PB-215 859

WATER QUALITY CONTROL STUDY NORTHEAST CAPE FEAR RIVER BASIN NORTH CAROLINA

Federal Water Pollution Control Administration
Charlottesville, Virginia

February 1967

DISTRIBUTED BY:

NTIS

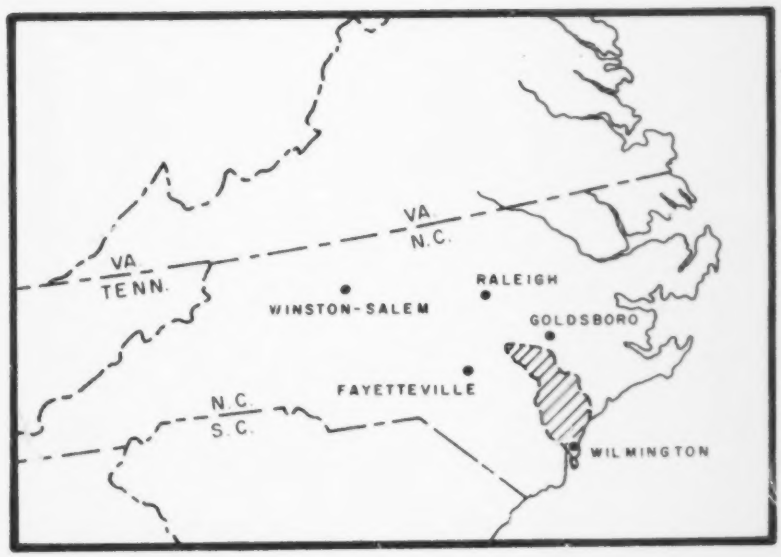
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

113

PB 215 859

WATER QUALITY CONTROL STUDY
NORTHEAST CAPE FEAR RIVER BASIN
NORTH CAROLINA

STUDY OF NEEDS AND VALUE OF STORAGE FOR
WATER QUALITY CONTROL



Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
MIDDLE ATLANTIC REGION
CHARLOTTESVILLE, VIRGINIA
FEBRUARY 1967

73

WATER QUALITY CONTROL STUDY

NORTHEAST CAPE FEAR RIVER BASIN

NORTH CAROLINA

ABSTRACT

A study of the need for and value of streamflow regulation for water quality control, for present and future conditions, has been made for the Northeast Cape Fear River Basin, North Carolina. The future needs were based on the results of economic and demographic studies of the area. It was concluded that water quality control measures beyond secondary waste treatment were necessary to protect the beneficial water users in the basin. Storage in the proposed reservoirs would satisfy a portion of the water quality control needs of the basin.

PREPARED AT THE REQUEST OF THE

U. S. ARMY ENGINEER DISTRICT

WILMINGTON, NORTH CAROLINA

BY

U. S. DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
Middle Atlantic Region
Charlottesville, Virginia
February, 1967

TABLE OF CONTENTS

	Page
LIST OF TABLES	iii
LIST OF FIGURES	iv
I. INTRODUCTION	I-1
Request and Authority	I-1
Purpose and Scope	I-1
Acknowledgments	I-2
II. SUMMARY OF FINDINGS AND CONCLUSIONS	II-1
Findings	II-1
Conclusions	II-2
III. DESCRIPTION OF PROJECT	III-1
IV. DESCRIPTION OF STUDY AREA	IV-1
Location and Boundaries	IV-1
Geography and Topography	IV-1
Climate	IV-1
Principal Communities and Industries	IV-2
V. WATER RESOURCES OF THE STUDY AREA	V-1
Surface Water	V-1
1. Quantity	V-1
2. Quality	V-2
Ground Water	V-3
1. Quantity	V-3
2. Quality	V-3
VI. THE ECONOMY	VI-1
Introduction	VI-1
Present Economy	VI-1
Agriculture	VI-1
Manufacturing	VI-3
Non-Commodities	VI-5
Population	VI-5
Future Economy	VI-6
Economic Outlook	VI-6
Projections and Trends	VI-7
VII. WATER SUPPLY	VII-1

	Page
VIII. WATER QUALITY CONTROL	VIII-1
General	VIII-1
Present Waste Sources	VIII-2
Future Waste Estimates	VIII-4
Water Quality Criteria	VIII-6
Flow Regulation	VIII-7
IX. BENEFITS	IX-1
APPENDICES	
Appendix A - Water Quality Data	A-1
Appendix B - Municipal and Industrial Waste Discharges	B-1
Appendix C - Classification and Water Quality Standards of North Carolina Streams	C-1
Appendix D - Schedule of Classification Adopted and Assigned to the Waters of the Northeast Cape Fear River Basin	D-1
BIBLIOGRAPHY	

LIST OF TABLES

No.	Title	Page
V-1	Historical Stream Flows in the Northeast Cape Fear River Basin	V-1
V-2	Uncontrolled Streamflow at Faison Dam Site Based on 24 Years of Record	V-2
VI-1	Employment	VI-8
VI-2	Differential Employment Shift	VI-10
VI-3	Employment and Productivity Trends for Major Industrial Categories	VI-11
VI-3A	Productivity Trends Per Employee	VI-12
VI-4	Number and Size of Manufacturing Plants	VI-13
VI-5	Employment and Population Projections	VI-14
VIII-1	Municipal and Industrial Waste Projections	VIII-5
VIII-2	Required Streamflow for Water Quality Control Rockfish Creek at Wallace	VIII-9
VIII-3	Required Streamflow for Water Quality Control Northeast Cape Fear River at Confluence with Rockfish Creek	VIII-10
VIII-4	Probability of Streamflow Deficits in the Northeast Cape Fear River at Wallace in 2025 for Selected Flow Regulation Storage	VIII-11
IX-1	Comparative Costs of Feasible Water Quality Control Methods	IX-6

LIST OF FIGURES

No.	Title	Following Page
I	Study Area	Last Page
VI-1	Population Projections	VI-14
VIII-1	Schematic Diagram of Flow Regulation Systems	VIII-8
VIII-2	Percent Failure of Annual and Maximum Monthly Deficiencies vs. Storage Requirements Faison Site for Year 2025	VIII-10

I. INTRODUCTION

REQUEST AND AUTHORITY

The U. S. Army Engineer District, Wilmington, North Carolina, by letter dated June 22, 1965, requested the Public Health Service* to make a study to determine the need for and value of water quality control storage in potential projects in the Northeast Cape Fear River Basin. Final agreement on Public Health Service participation in the study was indicated in a letter from the District Engineer, Wilmington, dated October 26, 1965.

This study was made in accordance with the Federal Water Pollution Control Act as amended (33 U.S.C. 466 et seq.).

PURPOSE AND SCOPE

The objectives of this study were to: (1) identify present and future water uses within the Northeast Cape Fear River Basin; (2) estimate future waste loads based upon economic projections; (3) determine the effects of present and future waste loads on water quality in the basin under natural streamflow conditions; (4) determine waste treatment and streamflow required to meet established water quality objectives; and (5) determine the need for and value of reservoir storage for water quality control.

The study area included the entire Northeast Cape Fear River Basin and the Wilmington, North Carolina, metropolitan area. Geographically, this area includes the Counties of Duplin and Pender and the major portion of New Hanover County.

The project period commencing in 1975, and extending to 2025, and present condition were evaluated in the study. The need for and value of storage for regulation of streamflow for water quality control was estimated for the beginning and end of the study period and for the intermediate years 1985 and 2000.

---

* The Water Quality Act of 1965, amended the Federal Water Pollution Control Act, transferring water pollution control responsibilities from the Public Health Service to the Federal Water Pollution Control Administration, effective December 31, 1965.

ACKNOWLEDGMENTS

U. S. Army Engineer District, Wilmington, North Carolina

U. S. Geological Survey, Raleigh, North Carolina

U. S. Bureau of Sport Fisheries and Wildlife, Atlanta, Georgia

North Carolina State Stream Sanitation Committee, Raleigh, North Carolina

North Carolina State Board of Health, Raleigh, North Carolina

North Carolina Fish and Wildlife Service, Raleigh, North Carolina

Duplin County Agricultural Extension Service, Duplin County, North Carolina

Pender County Agricultural Extension Service, Pender County, North Carolina

II. SUMMARY OF FINDINGS AND CONCLUSIONS

FINDINGS

1. The U. S. Army Engineer District, Wilmington, North Carolina, is making a study of the Northeast Cape Fear River Basin to determine the feasibility of constructing multiple-purpose reservoirs for water resource development. Kornegay Reservoir on the upper Northeast Cape Fear River and Faison Reservoir on Goshen Swamp are under consideration for development for flood control, recreation and water quality control.

2. The study area encompassed the Northeast Cape Fear River Basin and the Wilmington metropolitan area. The drainage area of the basin is approximately 1,750 square miles, and includes the counties of Duplin, Pender, and New Hanover and minor parts of Wayne, Onslow, and Sampson Counties.

3. Population of the study area was approximately 130,500 in 1960. Approximately 50,000 persons or 38 percent of the population were located in the Wilmington urban area, an additional 15,000 persons or 11.5 percent were located in small urban areas. The remaining 65,000 persons were located in rural areas of the basin.

4. With the exception of Wilmington, there are no large municipal water users of waste producers in the study area. Municipal waste in the basin, excluding Wilmington, had a population equivalent before treatment of 10,300 in 1965. Secondary treatment provided for five major sources in the upper portion of the basin, exhibits an overall average biochemical oxygen demand removal of 73 percent. Wilmington discharged wastes with a population equivalent of 44,700 in 1965, without treatment.

5. Textile mills and food processing plants, including pickle and poultry processing are the major industrial waste sources in the basin outside of the Wilmington area. Total industrial waste discharges from these sources averaged 2.75 million gallons per day (mgd) in 1965, with a population equivalent of 14,600 after treatment. Secondary treatment is provided for most wastes, and averages 75 percent biochemical oxygen demand removal. Industrial waste discharges were not determined for the Wilmington Area.

6. Average daily water use from surface supplies in the study area was approximately 7 mgd in 1965. Ground water use in the basin averaged 5 mgd in 1965, and was utilized for industrial process water and municipal supply for a population of 16,000.

7. Surface water quality is significantly affected throughout the basin by swamp drainage. During low flow periods low pH and high color render the water unsuitable for most domestic or industrial uses. Ground water quality is satisfactory throughout the basin, and is suitable for domestic or industrial use. The average dissolved solids for the groundwater is 215 milligrams per liter (mg/l) and the hardness averages 150 mg/l.

CONCLUSIONS

1. The population of the study area is expected to increase to 301,000 by the year 2025. It is expected that the majority of the growth will occur in the Wilmington urban area with a population of 200,000 predicted for the year 2025. The remainder of the increase will be scattered throughout the Northeast Cape Fear Basin with increases in the population of small municipalities partly offset by reductions in rural population.

2. Ground water resources are adequate to meet municipal and industrial water supply needs in the basin for the foreseeable future. Future water needs of the Wilmington urban area can be met from ground water supplies and the Cape Fear River.

3. A need for flow regulation of water quality control exists in Rockfish Creek and the Northeast Cape Fear River near Wallace. Residual waste loads from municipal and industrial sources at Wallace exceed available stream assimilative capacities even with secondary treatment providing 85 percent removal as measured by Biochemical Oxygen Demands (BOD).

4. A flow of 30 cubic feet per second (cfs) will be required in the Northeast Cape Fear River at Wallace for water quality control during the critical season in 1975. The required flow will increase to 90 cfs by 2025.

5. Flow regulation needs on the Northeast Cape Fear River may be met by flow regulation storage in either Falson or Kornegay Reservoirs. Approximately 10,800 acre-feet of storage would be required in the year 2025.

6. The water quality objective for the Northeast Cape Fear River can most economically be met by providing a single purpose reservoir at the Falson site. The average annual cost is estimated to be $75,000.

Reproduced from best available copy.

7. The annual value of benefits from control of quality beyond that possible by secondary treatment in the Northeast Cape Fear River is considered to be equal to the annual cost of a single purpose reservoir at the Faison site. The benefits are considered widespread in scope. Water quality management will help maintain over 30 miles of stream in the lower portion of the basin.

8. The value of fish and wildlife benefits for the Northeast Cape Fear River was determined to be $30,000 annually which includes both sport and commercial fishing interests.

9. The value of benefits attributed to the proposed reservoir is dependent upon the release of water high in dissolved oxygen. Provisions should be incorporated in the outlet design which would allow maximum flexibility for the release of high quality water and appropriate equipment should be provided to monitor reservoir releases and stream quality. Water quality releases should be made on the basis of stream needs as determined by the responsible water pollution control agency from information obtained through water quality monitors and other data.

10. Flow regulation needs of the metropolitan Wilmington area, and the Cape Fear River Estuary were not determined and are beyond the scope of this study. A comprehensive study of the Cape Fear River Basin and Estuary will be necessary to determine the water quality control needs of the Wilmington area. However, regulation provided by these projects can be expected to contribute to water quality management in the lower Cape Fear River and Estuary.

III. DESCRIPTION OF PROJECT

Two reservoir sites located in the upper portion of the Northeast Cape Fear Basin are under consideration by the Corps of Engineers for multiple-purpose development for flood control, recreation, and flow regulation for water quality control. (See Figure 1). Kornegay Reservoir site is located on the Northeast Cape Fear River approximately 105 miles above its mouth. Faison Reservoir site is located on Goshen Swamp approximately 9 miles above its confluence with the Northeast Cape Fear. Both reservoir sites are located in Duplin County.

Kornegay Reservoir with a surface area of 3,200 acres at conservation pool elevation and Faison Reservoir with a surface area of 1,800 acres will flood relatively flat swampland. The maximum depth of each reservoir will be approximately 30 feet.

Kornegay and Faison Reservoirs, with drainage areas of 115 square miles and 112 square miles, respectively, each control approximately 6.5 percent of the total basin. The watershed above each reservoir contains significant areas of swampland.

IV. DESCRIPTION OF STUDY AREA

LOCATION AND BOUNDARIES

The Northeast Cape Fear River is the largest tributary of the Cape Fear River and has a drainage area of 1,750 square miles or about 20 percent of the Cape Fear Basin. Since the confluence of the two streams occurs in tidal waters at Wilmington, water quality in the Northeast Cape Fear basin exerts influence on the Cape Fear River only in the estuarial portion.

The watershed boundary approximates an oval with the length approximately twice its width. The drainages of the Neuse River on the north, the New River on the east, small coastal streams on the southeast, and the Black River, another major tributary of the Cape Fear River, on the west abutting the basin. The Northeast Cape Fear originates near Mt. Olive at the northern edge of the basin and flows generally southward for 120 miles to its mouth at Wilmington. Significant tributaries are Holly Shelter Creek, Rockfish Creek, and Goshen Swamp (see Figure 1).

GEOGRAPHY AND TOPOGRAPHY

Unlike the major Cape Fear River basin which originates in the Piedmont physiography region with steep stream gradients and rolling topography before gradually flattening as it nears the coast, the Northeast Cape Fear basin lies entirely within the Coastal Plain province. The topography is very gently rolling near the headwaters to flat near the coast. Elevation varies from sea level to a maximum of 190 feet. Numerous swamps are located throughout the basin with two large swamps in the lower basin having an area in excess of 250 square miles. It is estimated that approximately one-fourth of the basin is in swampland.

Although drainage is generally poor, stream channels are well defined. The main stem has an average fall of 0.6 per miles; however, the lower 40 miles of the river are considered tidal.

CLIMATE

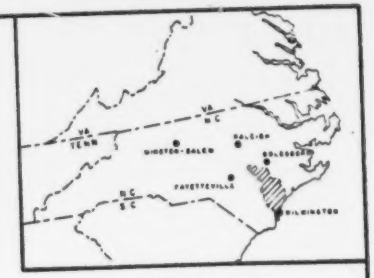
A mild climate with warm summers and moderate winters is characteristic of the basin. The average annual temperature is 63 degrees with monthly averages varying between 48 degrees in January and 79 degrees in July. Extended periods of freezing weather are rare in this region.

Rainfall is generally evenly distributed throughout the basin and averages 48 inches annually. Monthly averages indicate good distribution of rainfall with a minimum rainfall of 3.2 inches occurring in January and a maximum rainfall of 7.1 inches occurring in July. An occasional hurricane exerts influence on average rainfalls also as the basin is located in a prime hurricane area.

PRINCIPAL COMMUNITIES AND INDUSTRIES

With the exception of the Wilmington area, population and industry are sparsely scattered throughout the study area. Wilmington, with a 1960 population of 49,533, is the only large municipality in the area. Five small cummmunities, Mt. Olive, Beulahville, Wallace, Burgaw and Rose Hill, with populations between 1,000 and 5,000 are the only other significant population centers.

Industry is primarily concentrated in the Wilmington area. Significant industries located in the basin outside of the Wilmington area are Mt. Olive Pickle Company, Cates Pickle Company at Faison, Rose Hill Poultry Company, and J. P. Stevens and Company at Wallace.



LOCATION MAP

N

xxxxxxxxxxxxxxxxxxxxxxx
See the following pages
for greater detail.
xxxxxxxxxxxxxxxxxxxxxxx

WATER QUALITY CONTROL STUDY
NORTHEAST CAPE FEAR RIVER BASIN

STUDY AREA

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
MIDDLE ATLANTIC REGION CHARLOTTESVILLE, VA.

FIGURE 1

9-a

MOUNT OLIVE
WAYNE CO.
DUPLIN CO.
FAISON
GOSHEN SWAMP
KORNEGAY DAM SITE
FAISON DAM SITE
WARSAW
BEULAVILLE
ROSEHILL
WALLACE
SAMPSON CO.
DUPLIN CO.
PENDER CO.
NEW HANOVER CO.
BRUNSWICK CO.
CAPE FEAR RIVER
NORTHEAST CAPE FEAR RIVER
BURGAW
WILMINGTON
ATLANTIC OCEAN
Angola Swamp
Holly Shelter Swamp
SCALE IN MILES
10 0 10 20 30 40

A

LOCATION MAP

BAY

OCEAN

N

30 40

WATER QUALITY CONTROL STUDY
NORTHEAST CAPE FEAR RIVER BASIN

STUDY AREA

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
MIDDLE ATLANTIC REGION CHARLOTTESVILLE, VA.

FIGURE 1

9-a B

V. WATER RESOURCES OF THE STUDY AREA

SURFACE WATER

1. Quantity

Surface water in the Northeast Cape Fear basin is generally plentiful with runoff averaging approximately 30 percent of rainfall or 14 inches per year. However, large variations in flow are frequent with very low flows having occurred in most months. Historical flows for the three U. S. Geological Survey gaging stations located within the basin are shown in Table V-1.

Table V-1

HISTORICAL STREAM FLOWS IN THE NORTHEAST CAPE FEAR RIVER BASIN

Location	Years of Record	Drainage Area Sq. Mi.	Mean Flow cfs	Stnd. Devn. cfs	Ave. 7-Day Low Flow 10 Yr. Freq
NECF R. @ Seven Springs	7	47.5	69	71	1.0
NECF R. @ Chinquapin	24	600	693	673	13
Rockfish Creek @ Wallace	10	63.8	94	90	0.9

Statistical analysis of historical flows also indicates the large annual and seasonal variations in flow that occur. Table V-2 presents a summary of the statistical analysis of historical flows by months for the Chinquapin gage with flows area-adjusted to the Faison dam site. Since the Kornegay dam site has similar topographic features and approximately the same drainage area, these same flows are assumed to apply to that site.

Table V-2

UNCONTROLLED STREAMFLOW AT FAISON DAM SITE
BASED ON 24 YEARS OF RECORD

Month	Mean Flow cfs	Std. Deviation cfs	Minimum Monthly Flow cfs
October	91	104	2
November	88	89	3
December	129	108	12
January	176	109	30
February	207	145	48
March	213	105	50
April	148	93	29
May	81	72	19
June	67	78	5
July	137	176	5
August	121	131	3
September	128	197	2
Yearly Average	133	129	--

Table V-2 indicates that average flows are the lowest during the months of May, June, October and November. However, the large standard deviations for the months of July, August, and September indicate that very low flows may occur during these months also. Minimum monthly flows recorded for these months substantiates this.

2. Quality

During low flow periods, drainage from numerous swamps throughout the basin forms a large percentage of streamflow. Swamp drainage is characterized by low pH, a high color index, significant amounts of biochemical oxygen demand (3-4 mg/l.) and frequently by a very low dissolved oxygen content.

Water quality is significantly affected by swamp drainage even during normal flow periods. Increased runoff following low flow periods tend to flush large quantities of swamp water into the main streams resulting in marked effects on water quality. Color units remain high throughout the entire flow regime with a range of 100 to 400 common. The pH of the Northeast Cape Fear is generally near neutral at normal flow. However, for very low or very high flows, pH readings below 5.5 have been obtained.

Appendix A contains water quality data for selected stations in the Basin collected by the North Carolina State Stream Sanitation Committee. These data were collected in late summer 1955. Heavy rainfall produced high runoff and flushing of the swamps during the sampling period, thus the 1955 data reflects water quality during both low and high flow periods. Additional data collected in the summer of 1956, is indicative of average quality conditions.

Surface waters of the basin are not used for domestic or industrial supplies because of the persistence of color and low pH that necessitate expensive treatment methods to produce suitable quality.

GROUND WATER

1. Quantity

Ground water is in abundant supply within the basin. The entire area is underlain by varying amounts of unconsolidated sediments that yield substantial water supplies. Existing wells with depths from 50 to 300 feet yield 10 to 200 gallons per minute. With the exception of Wilmington, all municipalities in the study area utilize ground water sources as do most industries. The present scattered location of wells does not produce significant lowering of water tables. Ground water reserves are considered adequate for large increases in usage.

2. Quality

Ground water quality is satisfactory throughout the basin with average dissolved solids of 215 mg/l and a hardness of 150 mg/l. It is suitable for domestic or industrial uses with little or no treatment. Most supplies in the basin provide only chlorination. Some problems with iron and hydrogen sulphide have occurred in wells near the coast; however, changing the depth at which water is taken from the aquifer or minor relocations of wells frequently produces suitable water quality.

VI. THE ECONOMY

INTRODUCTION

For the purpose of economic analysis, the Northeast Cape Fear River Basin will include the North Carolina counties of Duplin, New Hanover, and Pender. This is an area covering 1,873 square miles, or 3.8 percent of the total area of North Carolina, and having a 1960 population of 130,538 representing 2.9 percent of North Carolina's population. The Basin is a predominantly agricultural area that has lagged behind the State in economic development but is now undergoing a relatively rapid change. Agricultural employment dropped from 39 percent of total employment in 1940 to 19 percent in 1960. Employment in manufacturing and services has absorbed some of the consequential excess labor, and out-migration has taken care of most of the residual. However, those manufacturing categories in which the Basin has manifested the greatest past growth has been in those industries that are nationally characterized as slow-growth industries; viz., food processing, textile mill products, and apparel and related products. Given the direction of its present development, industrialization is not expected to show large increases in the future. However, food processing and textile production may be significant water users and should not be overlooked.

Wilmington is the only municipality in the basin having a population of more than 5,000. Wilmington had a 1960 population of 49,533 and is situated at the confluence of the Northeast Cape Fear and the Cape Fear Rivers in New Hanover County. It serves as one of North Carolina's more important seaports and as the retailing center for an area extending approximately from Jacksonville on the northeast to Wallace on the north and to Conway, South Carolina on the southwest; an area with a radius of approximately 50 miles.

PRESENT ECONOMY

1. Agriculture

As measured by employment, agriculture is the most important commodity industry in the area. Table VI-1 shows the historical trends 1940-1960. The rapid decline in the absolute number employed and the decline as a percent of total employment should be noted. The decline has been brought about through more scientific methods, consolidation of holdings, and by greater efforts toward diversification.

The increase in the average size farm from 63 acres in 1950 to 78 acres in 1959 facilitated the mechanization of farms and the application of more scientific methods as well as a decrease in the number of farms from 8,590 in 1950 to 6,182 in 1959. Greater efficiency and larger size of farms are likewise implied in the increase in the number of farms selling $10,000 or more of farm products per year. The number in this category increased from 0.9 percent of the total number of farms in 1950 to 13.9 percent in 1959.

Part of the increase in efficiency is due to the greater diversification of farm products. By so diversifying, a more continuous output can be obtained resulting in a higher return of invested capital. In 1949, the total value of farm products sold amounted to $7.6 million, approximately 71 percent of which were accounted for by tobacco while in 1959 tobacco only accounted for 41 percent of the $18.2 million of farm products sold. (Total value of farm products sold in both years are in 1910-14 prices.) During the same period, poultry production increased from 3 percent of the total value of farm products sold to 24 percent. Other livestock products increased 10 to 13 percent. During more recent years, 1961-1965, cotton has declined, while corn and soy-beans have showed a marked increase in output. Table VI-3A clearly illustrates the tendency toward greater efficiency. The total value of farm products sold per employee increased 271.8 percent in the Basin between 1949 and 1959 compared to an increase of 169.8 percent in North Carolina and 132.9 percent in the Nation. The change in total agricultural production (Table VI-3) also was greater between 1949 and 1959 than it was for the State or Nation. Diversification, improved farming methods, the greater use of fertilizers, and the increased use of farm implements increased output figures to a greater extent in the Basin than in the State or Nation.

In summary, the Basin's economy has been dominated by agricultural production in the past but is diversifying its agricultural sector and also shifting its economic base so as to be less dependent upon agriculture. Table VI-1 indicates the shift in employment out of agriculture, and Table VI-2 presents a measure of the rapidity of the actual shift.

Irrigation in the Basin is relatively insignificant. Contact with the agricultural specialist in the area indicated that natural rainfall is generally sufficient. The total acres irrigated in Duplin and Pender Counties increased from 580 in 1954 to 1,155 in 1959. Irrigated land in New Hanover County decreased from 758 acres in 1954 to 174 in 1959.

2. Manufacturing

Manufacturing is the second most important employment category in the commodity group. A look at Table VI-1 will show the historical trends. In general, durable goods, within which there is one notable exception, show a decline relative to total employment. The exception is the increase in fabricated metals between 1950 and 1960, from 0.1 percent of total employment to 0.2 percent.

Nondurable goods employment, however, has shown a steady increase from 1940 to 1960, increasing from 7.1 percent of total employment to 12.7 percent of total employment. With only two exceptions in the nondurable group--chemicals and allied products and printing, publishing, and allied products--every nondurable category shows a gain relative to total employment, textile mill products showing the greatest gain followed by apparel and related products.

However, if the Basin's locational advantage relative to the State is considered, another trend is also observed. (See Table VI-1) Of the total 14 manufacturing categories, only 4 show an increasing Location Quotient (L.Q.) from 1950 to 1960--fabricated metals, electrical machinery, textile mill products, and other nondurables.1/ Only fabricated metals shows any sizable increase.

1/ The location Quotient (L.Q.) is an index indicating the locational advantage of the area of concern for an industry. In this case, the Basin was compared with North Carolina. An index of one (1.00) indicates that the area has no positive or negative locational advantages relative to the State; an index greater than one (1.00) indicates the area has greater locational advantages than the State in general; and an index less than one (1.00) indicates the area has lesser locational advantages than the State generally.

The index is computed by the ratio: percent of total employment in an industry in the Basin to percent of total employment in the same industry in North Carolina.

All other categories show a declining L.Q.

The tendency in manufacturing output and employment is shown in Table VI-3. The favorable showing in total manufacturing relative to the State and Nation was due to the Basin's small base in 1947 ($162 million dollars in 1947-49 prices.) The addition of one medium sized textile plant, for instance, would show an inordinate increase in the Basin's output. Efficiency as measured by output per employee is substantially below that of the State or Nation (Table VI-3A). The growth in manufacturing has been primarily in four categories--fabricated metals, food and kindred products, textile mill products, and apparel and related products (see Table VI-1)--and these four categories have historically been slow-growth industries.2/ Consequently, increases in output per employee in manufacturing in the Basin have lagged behind increases realized in the State and Nation.

In summary, the Basin's total manufacturing employment has been growing at a slightly faster rate than it has in North Carolina, but primarily in those industries that are classified as slow-growth industries. In the case of textiles and apparel, the Basin's locational advantage lies in having an excess labor supply and an ample supply of good quality water. The textile plant at Wallace in Duplin County is reported to have been located there principally because of the quality of the area's ground water. The food and kindred industry is located in the area to be near their source of supply.

Manufacturing establishments now in the Basin are unevenly distributed and are concentrated in and near Wilmington in New Hanover County. Table VI-4 presents the total number of plants by size and industry. Of the total number of establishments, 61 percent were located in New Hanover County in 1964, primarily in and around Wilmington. In 1958, 59 percent of the total were located in New Hanover County. As noted, the total number declined from 181 plants in 1958 to 169 in 1964. Although there has been a shift from smaller to larger plants, the Basin can still be characterized as having a preponderance of small establishments. It is estimated that approximately 40 percent of total manufacturing employment is in plants employing less than 50 employees.

2/ National Planning Association, "American Industry in 1976 and 1985: Projections of Output, Employment, and Productivity," National Economic Projections Series, Report No. 64-1.

Mining activity is insignificant in the Basin, employing only 10 workers in 1960.

3. Noncommodities

Noncommodities employment, (i.e., total employment other than agricultural, mining, construction, and manufacturing employment) has comprised a larger portion of total employment in the Basin than in the State. Comparable figures for 1960, are as follows: 56 percent in the Basin and 49 percent in North Carolina. The apparent explanation is that Wilmington is the trading, service, and educational center for a much larger area than the Basin. As noted in Table VI-1, wholesale-retail trade and services account for the majority of noncommodity employment.

4. Population

The Basin has experienced an average annual rate of growth of 1.08 percent from 1940 to 1960 compared to 1.22 percent for North Carolina and 1.54 percent for the Nation. The population 25 years old and over that had completed at least four years of high school in 1960, accounted for 10.3 percent of the total population, and 2.6 percent of the total population in the above age bracket had completed four or more years of college. Comparable figures for the State are 9.6 percent and 3.2 percent respectively. However, most of the people having high school and college educations in the Basin are concentrated in and around Wilmington in New Hanover County. Those completing at least four years of high school there accounted for 18.7 percent of the population compared to 8.1 percent in Duplin and Pender Counties. Comparable figures for four years or more of college are 4.8 percent in New Hanover County and 1.6 percent in Duplin and Pender Counties. A glance at Table VI-3A will indicate the Basin's relative per capita income standings. The figures presented show the basin's per capita income in 1959 to be $1,103 or 13 percent below that of the State and 41 percent below that of the Nation.

Wilmington, with a 1960 population of 49,533, was the only municipality over 5,000 in the Basin. Seven municipalities, five of them in Duplin County, are located in the Basin with populations ranging between 1,000 and 5,000.

Out-migration in the Basin has been substantial. Between 1950 and 1960, a total 14,291 persons, 11.7 percent of the 1950 population, migrated to other areas. Of the total number of emigrants, 63.5 percent (9,055) were in the 20-34 age group.

FUTURE ECONOMY

1. Economic Outlook

Agriculture can be expected to continue to be economically important in the Basin as measured by the value of products sold, although agricultural employment is expected to continue its decline. Tobacco production, the present leading cash crop, is expected to continue its decline as a proportion of total products sold, but to increase in absolute terms at approximately the same rate as consumption of tobacco products increases. Fresh vegetables, canning vegetables, corn, hogs, and poultry are expected to show increases. In line with the greater emphasis on diversified crops, irrigation is expected to approach 4,000 acres by 1985. Agricultural employment is expected to decline to about 4000 workers by the year 1985. This reduction will result from the consolidation of farms into larger operating units facilitating greater use of machinery and more scientific methods of production. (See Table VI-5)

The area's primary attraction for manufacturing is an excess supply of labor and sufficient supply of adequate quality ground water. The major markets of Durham and Raleigh in the northwest and the seaport of Wilmington on the south are all within a hundred mile radius. Transportation appears to be adequate with the Atlantic Coast Line Railroad traversing the full length of the Basin, having Wilmington as the southern terminal and making connections with east-west lines at Wilmington and at Goldsboro and Wilson to the north of the Basin.

Disadvantages of the Basin for manufacturing are the lack of raw materials for other than agricultural products, the lower level of educational attainment of the mature labor force in Duplin and Pender Counties, the lack of any cultural center outside of Wilmington, and the lack of a diversified manufacturing base.

With these factors in mind, it is expected that manufacturing employment will approach 13,600 by 1985 and that nondurable goods will continue to expand at a slightly faster rate than durable goods. (See Table VI-5) The most significant change in durable goods is expected to occur in fabricated metals, employment in 1985 (800) projected to be double the 1960 figure. Food processing, textile mill products, and apparel are expected to continue to account for the major growth in nondurable goods. By 1985, employment in these categories is expected to be 2,200, 3,300, and 3,300 respectively.

Since Wilmington has the nucleus of a manufacturing base at present, the majority of the increase in manufacturing is expected to take place in and around the Wilmington area. Of the six textile plants in the Basin in 1964, five were located in the Wilmington area, and no new textile plants are expected to locate outside of this area in the near future. However, the single plant not in the Wilmington area (located at Wallace in Duplin County) is expected to significantly increase its output by expanding their present facilities. Labor supply is a more important consideration in the location of apparel and related products establishments, and plants of this type are expected to expand into the Upper Basin in the future. Food processing plants tend to be located near their source of raw material, and as Duplin and Pender Counties diversify their agricultural output toward vegetables and meat products (principally poultry), plants in the area will expand.

2. Projections and Trends

Population projections are presented in Table VI-5 and Figure VI-1. They are based upon employment projections to the year 1985 and projected by the share method, using North Carolina as the base, from 1985 to 2025. As noted in Table VI-5, population is expected to reach 165,000 by 1985 and 301,000 by 2025. Rural population is expected to decline as a result of the decrease in agricultural employment. At the same time, urban population is expected to increase from 38 percent of total population to 52 percent by 1985. Projections for particular municipalities are subject to considerable error because of their present small size.

The municipalities of Mt. Olive, Rose Hill, and Wallace were projected for the study period using the growth trends indicated in Figure VI-1. The combined water services area populations for these communities are represented in Figure VI-1 as the difference between the total urban and Wilmington water service projections. The water service areas were used to determine the domestic waste projection in section VIII.

The major waste producing industries in the basin, excluding the Wilmington area, are in the textile and food products categories. These industries are growing at a rate slightly faster than the State and will almost double their 1960 employment by 1985. The trends in textile and food products were evaluated and used in Section VIII to determine the industrial waste estimates that are indicated in Table VIII-1.

Table VI-1
Employment
Northeast Cape Fear River Study Area
1940 - 1960

	1940			1950			1960		
	Number	Pct.	L.Q.*	Number	Pct.	L.Q.	Number	Pct.	L.Q.
Agr., For., & Fish.	13,925	39.0	1.15	13,497	31.0	1.25	8,684	19.3	1.48
Mining	7	----	----	10	----	----	10	----	----
Construction	1,677	4.7	1.21	2,569	5.9	1.00	3,119	6.9	1.13
Manufacturing	4,587	12.8	.47	6,015	13.8	.49	7,865	17.5	.55
Durable Goods	2,043	5.7	.97	2,710	6.2	.84	2,144	4.8	.52
Furn., Lum., & Wd. Prod.	1,918	5.4	1.13	2,306	5.3	.93	1,406	3.1	.62
Primary Metals	61	0.2	.67	55	0.1	.50	21	----	----
Fabricated Metals**				54	0.1	.50	409	0.9	2.25
Machinery	22	0.1	.50	61	0.1	.25	63	0.1	.13
Electrical Machinery				11	----	.08	86	0.2	.13
Motor Vehicles & Equip.	2	----	----	5	----	----	8	----	----
Transportation Equip.	13	----	----	116	0.3	6.33	62	0.1	.50
Other Durable Goods	27	0.1	.25	102	0.2	.33	89	0.2	.25
Nondurable Goods	2,544	7.1	.33	3,305	7.6	.37	5,721	12.7	.56
Food & Kindred Prod.	536	1.5	1.36	885	2.0	1.54	1,177	2.6	1.24
Textile Mill Prod.	440	1.2	.08	639	1.5	.10	1,836	4.1	.30
Apparel & Related Prod.	387	1.1	2.20	706	1.6	1.60	1,442	3.2	1.52
Print., Pub., & Allied Prod.	178	0.5	1.25	312	0.7	1.17	333	0.7	.88
Chemicals & Allied Prod.	924	2.6	3.25	544	1.2	2.00	471	1.0	1.25
Other Nondurables	79	0.2	.08	219	0.5	.22	462	1.0	.34
Trans., Comm., & Util.	2,858	8.0	2.29	3,705	8.5	1.89	3,508	7.8	1.70
Wholesale-Retail Trade	4,383	12.3	1.16	7,181	16.4	1.15	8,341	18.5	1.16
Fin., Ins., & R.E.	459	1.3	1.00	797	1.8	1.06	1,320	2.9	1.07

Table VI-1
(Continued)

	1940			1950			1960		
	Number	Pct.	L.Q.*	Number	Pct.	L.Q.	Number	Pct.	L.Q.
Services	6,370	17.8	1.09	7.688	17.5	1.06	9,170	20.4	1.05
Government	856	2.4	1.41	1,484	3.4	1.31	1,858	4.1	1.32
Unreported	618	1.7	1.21	642	1.5	1.00	1,169	2.6	.84
Total	35,749			43,588			45,044		
Population	105,384			122,773			130,520		

* The Location Quotient (L.Q.) is an index indicating the locational advantage of the area of concern for an industry. In this case, the Basin was compared with North Carolina. An index of one (1.00) indicates that the area has no positive or negative locational advantages relative to the State; an index greater than one (1.00) indicates the area has greater locational advantages than has the State in general; and an index less than one (1.00) indicates the area has lesser locational advantages than has the State generally.

The index is computed by the ratio: percent of total employment in an industry in the Basin to percent of total employment in the same industry in North Carolina.

** During the year 1940 figures for Primary Metals and Fabricated Metals were combined. Figures for Machinery and Electrical Machinery were also combined.

Table VI-2
Differential Employment Shift
Northeast Cape Fear River Study Area
1950-60

	Number Employed 1960	Differential Employment Shift*
Agr., For., & Fish.	8,684	959
Mining	(Insignificant)	0
Construction	3,119	200
Manufacturing	7,865	375
Durable Goods	2,144	-1,568
Furniture, Lum, & Wd. Prod.	1,406	- 840
Fabricated Metal Prod.	409	259
Nondurable Goods	5,721	1,753
Food Processing	1,177	- 315
Textile Mill Prod.	1,836	1,177
Apparel & Related Prod.	1,442	- 149
Noncommodities - Total	25,366	-2,779
Total Employment	45,044	-2,803

* The differential shift is the numerical difference between what employment in the Basin would have been had it grown at the same rate as North Carolina and its actual growth, 1950-60. Positive figures indicate more rapid growth or less rapid decline, and negative figures indicate less rapid growth or more rapid decline.

Table VI-3
Employment and Production Trends for Major Industrial Categories
Northeast Cape Fear River Study Area

	Percentage Change in Employment *			Percentage Change in Production **		
	Basin	N.C.	U.S.	Basin	N.C.	U.S.
Agriculture	-35.7	-42.8	-38.2	139.2	54.1	44.0
Manufacturing	30.8	24.5	19.3	51.9	44.3	46.5
Services	18.0	30.9	26.3			
Total	3.3	9.8	14.5			
Income ***					121.1	105.5

* Employment trends for all categories are for the years 1950 - 1960.

** Agricultural change in production computed on the total value of farm products sold in 1949 and 1959, 1910-14 prices. Manufacturing data computed on value added basis (in 1947-49 prices) 1947 and 1958.

*** 1950-1959 inclusive, 1957-59 prices. No income data is available by county except for 1959.

Table VI-3A
Production Trends Per Employee
Northeast Cape Fear River Study Area

	Percentage Change *		
	Basin	N.C.	U.S.
Agriculture Per Employee	271.8	169.3	132.9
Manufacturing Per Employee	5.1	20.8	35.8
Income ** Per Capita	$1,103	$1,271	$1,878

* Agricultural change per employee computed on the total value of farm products sold in 1949 and 1959 using employment as reported in 1950 and 1960. Manufacturing data computed on value added basis (in 1947-49 prices) and employment 1947-1958.

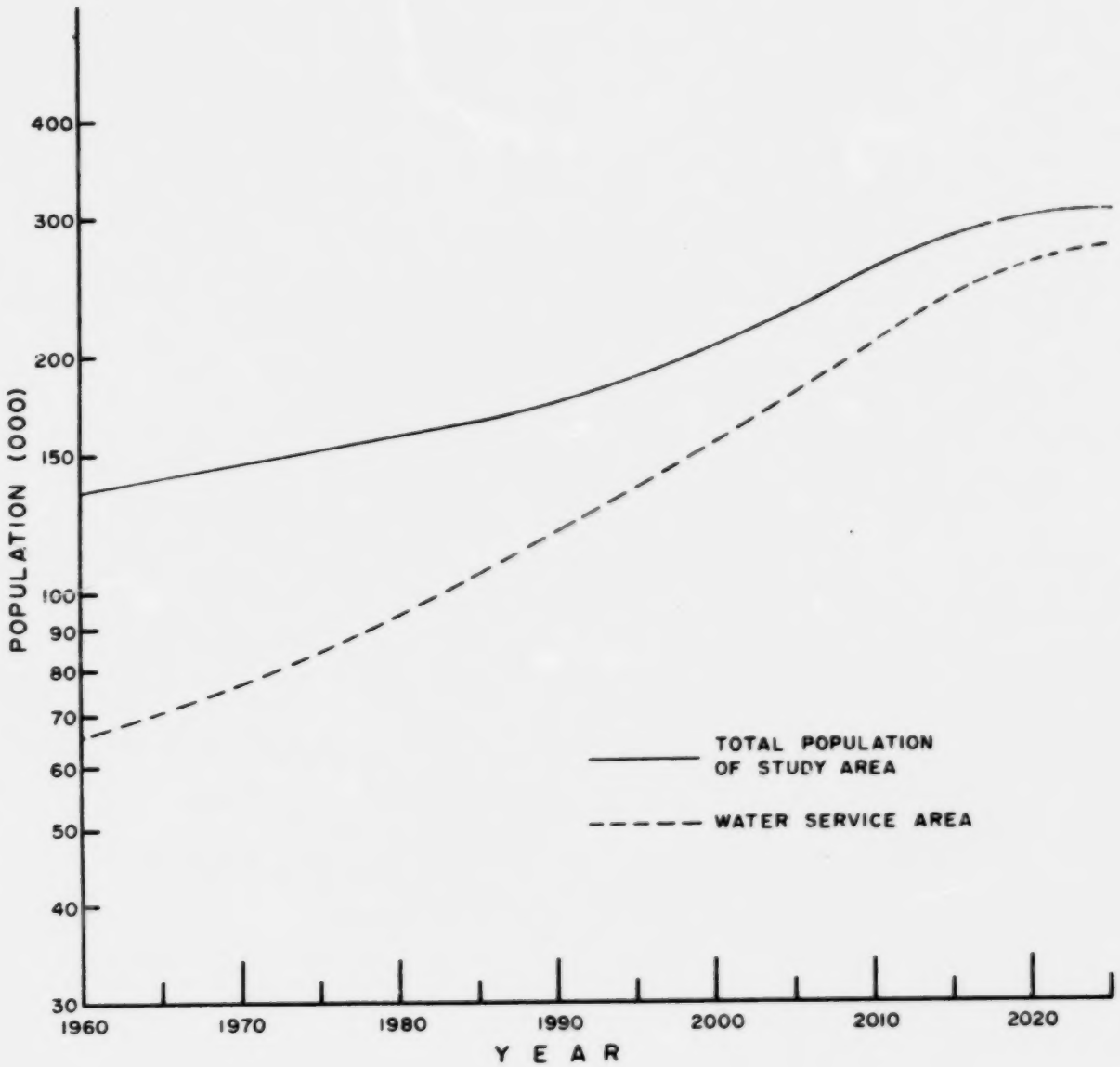
** Per capita income is as of the year 1959 in current prices.

Table VI-4
Number and Size of Manufacturing Plants
1958 and 1964
Northeast Cape Fear River Study Area

Employment Categories	Plants Employing 1-49		Plants Employing 50-99		Plants Employing 100-249		Plants Employing 250-499		Plants Employing 500-999		Total No. of Plants	
	1958	1964	1958	1964	1958	1964	1958	1964	1958	1964	1958	1964
Food and Kindred Prod.	30	37	4	6	3	4					37	47
Textile Mill Prod.			1	1		1	2	1	1	3	4	6
Apparel & Related Prod.	3	2		2	3	3	2	1		1	8	9
Lumber & Wood Prod.	77	38	2	4	4	3					83	45
Furniture & Fixtures	5	1									5	1
Paper & Allied Prod.	1	2									1	2
Print., Pub., & Allied Prod.	10	13			1	1					11	14
Chemicals & Allied Prod.	7	10	1	2		1					8	13
Petroleum Refin. & Rel. Ind.	2	4									2	4
Leather Products	1										1	
Stone, Clay & Glass Products	6	7				1					6	8
Fabricated Metals	6	4		1					1	1	7	6
Machinery, except Electrical	2	7				1					2	8
Transportation Equip.	4	2									4	2
Instruments		2										2
Miscellaneous	2	2									2	2
Total Number of Plants	156	131	8	16	11	15	4	2	2	5	181	169

Table VI-5
Employment and Population Projections
Northeast Cape Fear River Study Area

	1960	Percent	1975	Percent	1985	Percent	2005	2025
Agriculture, Forestry, & Fisheries	8,684	19.3	5,500	10.8	4,000	7.3		
Mining	10	----	15	----	20	----		
Construction	3,119	6.9	3,800	7.5	4,300	7.8		
Manufacturing	7,865	17.5	11,500	22.6	13,600	24.8		
Durable Goods	2,144	4.8	2,300	4.5	2,700	4.9		
Fabricated Metals	409	0.9	450	0.9	800	1.5		
Nondurable Goods	5,721	12.7	9,200	18.1	10,900	19.9		
Food & Kindred Prod.	1,177	2.6	1,700	3.3	2,200	4.0		
Textile Mill Prod.	1,836	4.1	2,700	5.3	3,300	6.0		
Apparel & Rel. Prod.	1,442	3.2	2,500	4.9	3,300	6.0		
Services	25,366	56.3	30,000	59.1	32,900	60.0		
Total Employment	45,044		50,800		54,800			
Population	130,520		154,200		165,000		227,000	301,000
Urban	49,600		64,900		86,000		136,000	255,000
Water Service Area	66,100		84,000		106,000		159,000	271,000



POPULATION PROJECTIONS NORTHEAST CAPE FEAR RIVER STUDY AREA

FIGURE VI-1

VII. WATER SUPPLY

Determining the need for and value of water supply was not an objective of the study; but because of the relationship between water supply needs, waste loads and the basin's water resources, a brief discussion of current water supply uses has been included.

Water supply in the study area is not a problem. The low population density and the lack of large water-using industries combine to exert only a small demand on the available supply of water. A survey of existing supplies indicated that adequate capacity exists for meeting present needs and those of the immediate future. Reserve supplies are available for development to meet all needs in the foreseeable future.

Municipal and industrial water supplies are primarily obtained from ground water with the exception of several industries at Wilmington which obtain surface water from the Cape Fear River. It is estimated that surface water use in the basin excluding Wilmington totaled 1 mgd in 1955 and increased to 2 mgd in 1965. Surface water use by Wilmington totaled 5 mgd in 1955 increasing to 5 mgd in 1965. Ground water use was estimated at 2 mgd in 1955 increasing to 5 mgd in 1965. It is anticipated that the water needs of the basin will not increase greatly outside of the Wilmington area. However, the location of one large water-using industry in the basin would have a significant impact on water needs. Water needs in the Wilmington area will be met primarily from the Cape Fear River with some industrial supplies obtained from ground water.

Irrigation is not a major water user in the basin. Approximately 3,000 acres of tobacco, flowers, and truck farming receive some irrigation. Peak irrigation occurs during the months of May and June. The majority of the irrigation supply is obtained from small ponds with some obtained from small streams. The remoteness of fields from large streams prevents significant use from these sources. It is estimated that irrigation presently consumes 3,000 - 5,000 acre-feet per year. A major increase in irrigation is not anticipated.

As the peak irrigation season does not coincide with the most critical streamflow periods and the irrigation supply is obtained primarily from small ponds, future increases in irrigation are not expected to result in significant reductions in streamflow during critical periods.

VIII. WATER QUALITY CONTROL

GENERAL

Water quality control measures are necessary if the beneficial uses of the basin's water resources are to be maintained. Without control measures water quality will be degraded and the economic growth, health, and welfare, recreation, fish and wildlife and general esthetics of the basin would be adversely affected. As the water quality is reduced only beneficial users requiring low water quality will enjoy continuous growth without providing special water treatment facilities and the basin would realize tangible economic losses associated with limitations imposed upon beneficial users requiring high quality water.

Ideally then, control measures should be applied to maintain water quality at a level which would meet all needs of a basin. Economical and efficient application of water quality control measures is dependent upon the determination of the present and future uses of water resources of the basin, the selection of appropriate water quality objectives for each reach that will allow the designated uses, and the determination of the most feasible methods of maintaining these objectives.

Present and possible future water uses in the study area may be divided into five broad categories arranged in order of generally decreasing water quality requirements. These are water based recreation including swimming and fishing; domestic, commerical and industrial water supply; propagation and survival of aquatic life; agricultural use including irrigation; and assimilation of waste.

Streams within the study area receive pollutants from both natural and man-made sources that reduce water quality and make the streams less desirable for various uses. These pollutants may be classified as degradable or nondegradable depending upon whether or not they are reduced by biological life to other forms within the stream. Examples of nondegradable pollutants are chlorides and color. Their effect on water quality is primarily a function of concentration, high concentrations producing low water quality.

Degradable pollutants consist primarily of organic materials deposited in streams by nature or by waste discharges. The organics are reduced to simple compounds by biological action which utilizes dissolved oxygen from the stream. Biochemical oxygen demand (BOD) is the amount of oxygen required for the biological reduction of organics and is a measure of the

concentration of organics in the stream. Each stream has an assimilative capacity of ability to satisfy BOD requirements and reduce degradable wastes within limits. The limits are dependent upon the rate at which a waste breaks down, the initial dissolved oxygen in the stream, the ability of the stream to reaerate or replenish depleted dissolved oxygen from the atmosphere and the concentration of BOD in the stream. If the total amount of organics discharged to a stream (BOD loading) exceeds its assimilative capacity, low dissolved oxygen levels will result.

Waste treatment is the most common method of water quality control in the study area. In accordance with the recommendations of the North Carolina Stream Sanitation Committee, secondary treatment is to be provided for all waste sources in the basin before 1975. However, under present conditions residual waste loads remaining after secondary treatment have exceeded stream assimilative capacities during periods of low streamflow and resulted in degradation of water quality. Therefore, other methods of quality control must be utilized in combination with secondary treatment to protect water quality.

Flow regulation is a frequently applied quality control method. Increasing streamflow during low flow periods generally results in improved water quality and other beneficial effects. The applicability of flow regulation to control of water quality within the basin was investigated.

Federal construction agencies, in the planning of any reservoir, are required by the Federal Water Pollution Control Act to give consideration to the inclusion of storage for regulation of streamflow for water quality control purposes. The Act also requires that flow regulation shall not be provided as a substitute for adequate treatment or other methods of controlling waste at the source. For the basis of this study secondary treatment with removal efficiencies of 80 to 85 percent as measured by BOD removal has been considered adequate treatment.

The following sections of this chapter are devoted to an analysis of present and future waste sources, selection of water quality objectives and determination of flow regulation needs of problem areas.

PRESENT WASTE SOURCES

Basin streams receive waste discharges from municipal and industrial sources at a few widely scattered locations. With the exception of the areas discussed below, water quality throughout the basins is not significantly affected by wastes from these sources. Natural pollution, produced primarily by swamp drainage, results in significant reductions in water quality.

Sources of municipal and industrial wastes are located at Mt. Olive on the Northeast Cape Fear, Faison on Goshen Swamp, Rose Hill on Island Creek, Beulahville on Muddy Creek, Wallace on Rockfish Creek, Burgaw on Burgaw Creek, and at Wilmington on Smith Creek and the Northeast Cape Fear.[2] These waste sources are listed in Appendix B. With the exception of the Mt. Olive Pickle Company and the City of Wilmington, all waste sources receive some form of treatment. Treatment efficiencies range from 30 to 94 percent in terms of BOD removal.

Waste sources in four areas were of interest with respect to their effects on water quality. Mt. Olive discharges 0.4 mgd of domestic wastes to the Northeast Cape Fear River after secondary treatment. Mt. Olive Pickle Company discharges approximately 0.15 mgd of industrial wastes to a tributary of the Northeast Cape Fear River without treatment. In the past (1955), the BOD of the pickle waste was very high with a population equivalent (P.E.) of 20,000. Fish kills occurred at various times for several miles downstream on the Northeast Cape Fear River during low flow periods. The P.E. of the pickle waste has since been reduced to 2,700 by in-plant waste reductions. Treatment facilities are in the planning stage that will provide the equivalent of secondary treatment and further reduce the discharge from the plant. However, the treatment facilities will not reduce the amount of chlorides, discharged from brine wastes. The concentration of these wastes is in the range of 20,000 mg/l.

The municipal and industrial waste discharges at Mt. Olive are located upstream from the proposed Kornegay Reservoir. However, the small waste discharges and available natural dilution will reduce the concentrations of nutrients and chlorides to acceptable levels.

A similar situation exists at Faison where the city discharges approximately 0.07 mgd of domestic wastes to Reedy Branch after primary treatment. Cates Pickle Company discharges approximately 0.001 mgd of brine wastes to a tributary of Goshen Swamp. The small waste discharge, application of treatment, and available dilution will prevent any water quality problems in Goshen Swamp Creek.

Existing waste discharges at Wallace include 0.35 mgd from the city's new 0.5 mgd secondary treatment plant and 2.2 mgd from J.P. Stevens' new 3.0 mgd industrial waste plant. The waste loads discharged to Rockfish Creek are expected to produce critical water quality problems below Wallace during low flow periods.

Smith Creek near Wilmington is the recipient of numerous discharges of wastes from both municipal and industrial sources. Water quality in the creek is badly degraded. A major sewer discharges untreated municipal wastes from Wilmington to the creek. In addition, Wilmington discharges untreated wastes from a total population of approximately 45,000 to the Northeast Cape Fear River and Cape Fear River through numerous outfalls. Smith Creek, the Northeast Cape Fear River and the Cape Fear River are all affected by tides in this area. Consequently, water quality in the entire estuary is reduced by the tidal cycling of wastes from industry and Wilmington.

The extensive areas of swampland within the basin contribute large amounts of natural pollution that results in degradation in water quality throughout the study area. Water courses draining swamps, such as Holly Shelter Creek, discharge significant BOD loads to the Northeast Cape Fear River.

FUTURE WASTE ESTIMATES

Municipal and industrial waste estimates for the study area were made utilizing data on estimated population and industrial growth presented in Chapter V, The Economy. Municipal waste estimates were based on the projected population growth of the basin. Industrial waste estimates were based on predicted industrial expansion within the basin and increased productivity within each industry. The projected waste discharges for significant areas for the years 1975, 1985, 2000, and 2025, are presented in Table VIII-1.

TABLE VIII-1

MUNICIPAL AND INDUSTRIAL WASTE ESTIMATES

Area	Population Equivalents 1975	1985	2000	2025
Mt. Olive				
Waste loadings prior to treatment				
Municipal and Industrial	8,800	10,200	13,100	14,700
Residual waste loadings after treatment	1,760	2,040	1,960	2,200
Rose Hill				
Waste loadings prior to treatment				
Municipal and Industrial	8,500	10,800	12,500	13,550
Residual waste loadings after treatment	1,700	2,160	1,870	2,030
Wallace				
Waste loadings prior to treatment				
Municipal and Industrial	86,000	116,500	158,300	183,000
Residual waste loadings after treatment	17,200	23,300	23,800	27,500

By 2025 all secondary treatment facilities in the basin should have removal efficiencies of 90 percent or greater. However, because of the predominance of industrial waste in the basin which varies in volume concentration, the small size of the treatment plants, limited supervision, and urban drainage, a treatment efficiency of 80 percent for 1975 and 1985 and 85 percent for 2000 and 2025 was used to estimate the total waste load reaching the receiving stream.

WATER QUALITY CRITERIA

Water quality is measured by a number of physical and chemical characteristics or indicators. Indicators which describe water quality and have a major effect on water use in the Northeast Cape Fear basin include color, pH, coliform bacteria, chlorides, temperature and dissolved oxygen. Each indicator was evaluated by comparing the concentrations with present and future water user needs for the basin and it was determined that coliform bacteria and dissolved oxygen were the most significant quality indicators. Color and pH have an influence on the basin's waters; however, because natural swamps were indicated as the source of these constituants, it was determined that any control measures such as flow regulation or treatment was beyond the scope of this study.

Bacterial contamination of a stream by human and animal wastes is measured by determining the most probable number of coliform per 100 milliliters. General limits have been set for various water uses such as domestic water supply and recreation. In the Northeast Cape Fear River recreation is the major water use affected by bacterial contamination. All waste in this category will be effectively treated to the satisfaction of the North Carolina State Stream Sanitation Committee after consideration has been given to the quantity and quality of the waste involved and the proximity of the discharge to the waters used for recreation. In view of this it has been assumed that bacterial contamination will be controlled at the source by disinfection and beneficial water uses attributed to recreation will not be limited by bacterial contamination.

Dissolved oxygen was selected as one of the most important and controlling water quality indicators. The commonly accepted dissolved oxygen levels for survival and propagation of warm water fishes range from 4.0 - 5.0 mg/l. An examination of data on the existing natural waters of the basin and the distribution of fish populations indicated that basin swamp waters frequently have dissolved oxygen less than 4.0 mg/l during the warm summer months and certain species of fish commonly found in swamp waters thrive and propagate with minimum dissolved oxygen of 3.0 mg/l.[8]

A dissolved oxygen objective of 4.0 mg/l was selected for the Northeast Cape Fear River from the proposed Kornegay Reservoir to its mouth at Wilmington. This objective will provide protection for propagation and survival of all types of warm water fishes found in the basin. Maintenance of the objective can be facilitated by release of water containing high dissolved oxygen levels from the proposed reservoir.

A second dissolved oxygen objective of 3.0 mg/l was selected for all tributary streams. This objective will protect water quality in these streams for the various species of warm water fishes commonly associated with small swamp streams.

The higher dissolved oxygen objective on the main stream will stimulate a more complete warm water fishery and provide greater protection for downstream commercial fishing interests.

The North Carolina State Stream Sanitation Committee has established similar dissolved oxygen objectives for basin streams.[2] The Committee has designated all basin waters as swamp waters with an assigned minimum dissolved oxygen of 3.0 mg/l. Classifications of basin streams and quality standards assigned by the State Stream Sanitation Committee are included in Appendix C.

The water quality objective selected for this study was based on existing and possible future uses of the basin's water resources. Maintenance of water quality above the minimum objective selected will protect basin surface water for the following uses:

1. Propagation and survival of fish, wildlife, and other aquatic life.

2. Waste assimilation after adequate treatment.

The maintenance of increased low flows to meet minimum dissolved oxygen objectives will also improve water quality for desired uses by reducing color and increasing pH.

FLOW REGULATION

Water quality as influenced by existing waste discharges was examined throughout the basin. Water quality was computed for affected reaches utilizing estimated waste loadings and assimilative capacities estimated from available data[2] and literature [9] and compared to the selected water quality objective. Secondary treatment was determined to adequately protect water quality in all critical areas with the exception

of Rockfish Creek and the Northeast Cape Fear at Wallace. An analysis of the two streams was made to determine if flow regulation was needed for quality control.

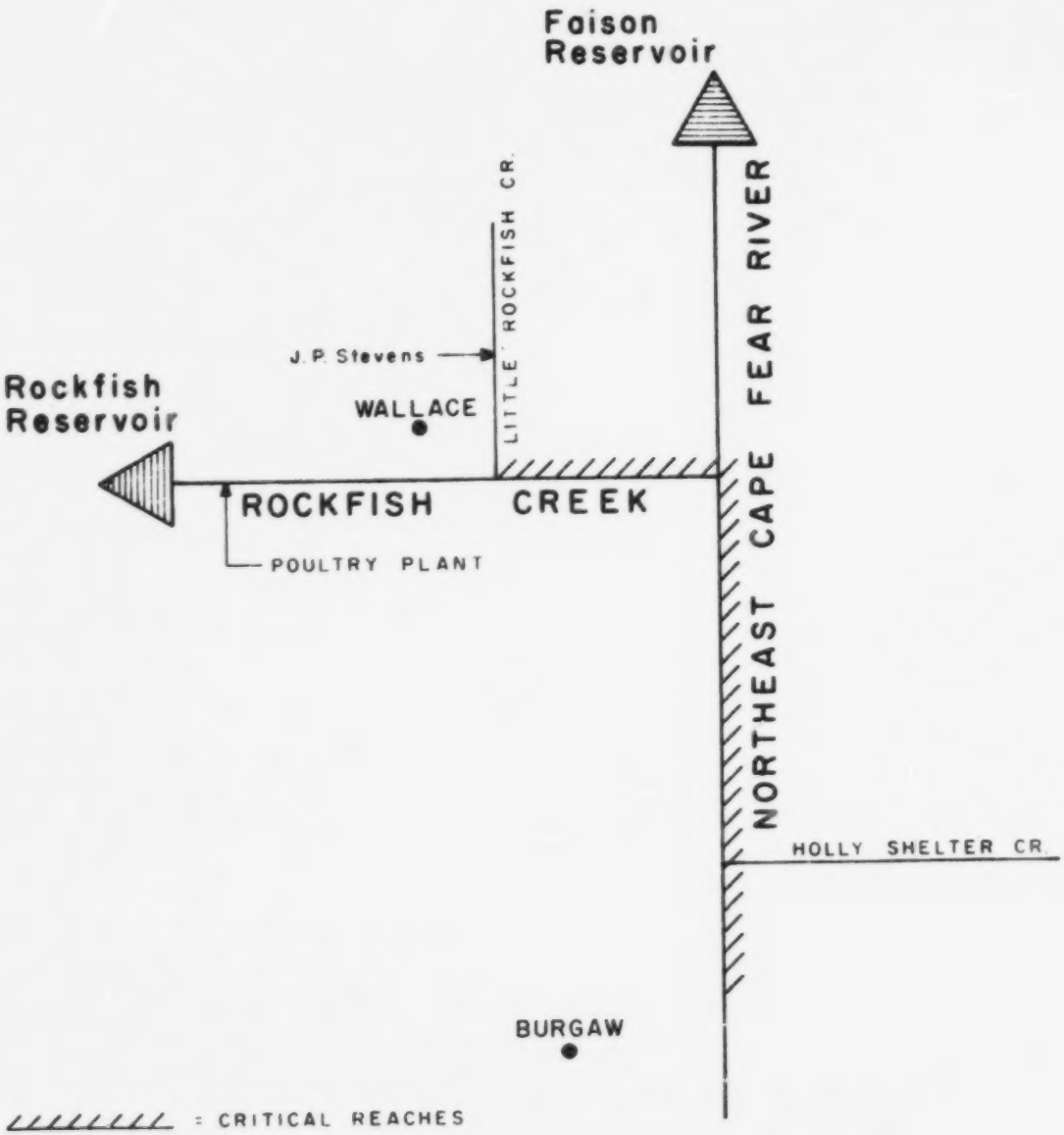
Rockfish Creek, with a drainage area of 169 square miles, is one of the larger tributaries of the Northeast Cape Fear River, joining it approximately 66 miles above Wilmington. Little Rockfish Creek joins the main creek 3.6 miles upstream from its confluence with the river. Water quality in the drainage area above sources of pollution is typical of streams receiving significant amounts of swamp drainage. Stream channels are well defined with average low flow velocities of 1.0 feet per second.

Waste sources in the Rockfish Creek watershed consist of the J. P. Stevens industrial waste treatment facility located on Little Rockfish Creek 1.5 miles above its mouth, the Wallace secondary treatment plant located on Rockfish Creek 1.9 miles upstream from Little Rockfish Creek and a proposed poultry plant which will discharge treated wastes to Rockfish Creek approximately 5 miles upstream from the Wallace plant. Residual wastes from these sources affect water quality in the lower 11 miles of Rockfish Creek and downstream reaches of the Northeast Cape Fear River. The relative locations of the waste sources and stream reaches are shown schematically in Figure VIII-1.

Rockfish Creek has an average annual discharge of 173 cfs and an average 7 consecutive day low flow occurring once in 10 years of 5 cfs. The assimilative capacity of the lower 3.6 miles reach was estimated at 1,560 pounds BOD per day or population equivalent (P.E.) of 7,800 in 2025. The assimilative capacity was based on maintenance of minimum dissolved oxygen of at least 3.0 mg/l in all of Rockfish Creek.

The Northeast Cape Fear River immediately upstream from Rockfish Creek has a drainage area of approximately 750 square miles and an average 7-day low flow occurring once in 10 years of 16 cfs. The assimilative capacity of the reach downstream from Rockfish Creek was estimated at 1,500 pounds BOD per day of P. E. of 7,500. This capacity was based on maintenance of minimum dissolved oxygen of at least 4.0 mg/l in the combined low flows including waste flow.

Comparison of expected waste loadings and assimilative capacities based on the 7-day low flow occurring once in ten years, indicated that BOD removal efficiencies of 88 percent at present, 92 percent in 1975 and 95 percent in 2025 would be required to maintain the water quality objective in the Northeast Cape Fear River. Thus, other water quality control measures in addition to secondary treatment of all wastes would be required.



SCHEMATIC DIAGRAM OF FLOW REGULATION SYSTEMS

FIGURE VIII - 1

The proposed Kornegay and Faison Reservoirs are located upstream from the critical reach of the Northeast Cape Fear and could be utilized for flow regulation in this reach. However, there are no existing or proposed reservoirs located in the Rockfish Creek watershed which could be utilized for flow regulation of that stream. Examination of topographical maps indicated a possible reservoir site on the upper reaches of Rockfish Creek near the confluence with Duff's Creek. The total drainage area above this site is approximately 62 square miles.

The location would provide flow regulation in the reach which will receive wastes from the proposed poultry plant as well as the critical reach below Wallace and would also provide flow regulation in the Northeast Cape Fear River.

Flow requirements in Rockfish Creek from the reservoir site to the Northeast Cape Fear River were computed for various waste loads, seasons and assimilative capacities utilizing both digital computer[10] and hand techniques. Flow requirements for the critical reach were estimated by month for the years 1975, 1985, 2000, and 2025. These requirements are presented in Table VIII-2.

Table VIII-2
REQUIRED STREAMFLOW FOR WATER QUALITY CONTROL
ROCKFISH CREEK AT WALLACE
(cfs)

Month	Year 1975	1985	2000	2025
January	5	5	5	8
February	5	5	5	8
March	5	7	8	10
April	5	7	8	15
May	12	15	19	20
June	15	20	22	30
July	22	30	33	42
August	22	30	33	42
September	22	30	33	42
October	15	18	20	25
November	8	10	10	15
December	5	5	5	10

Flows required to meet water quality objectives in the Northeast Cape Fear River below Wallace were also computed utilizing the same techniques as for Rockfish Creek. These flow requirements are presented in Table VIII-3.

Historical streamflow data were analyzed to evaluate the adequacy of various reservoir storages at the proposed sites to meet flow requirements. Streamflow sequences (representing a 500 year period) that preserved the statistical characteristics of the available data were generated by operational hydrology and utilized in the analysis. These flows were routed through reservoirs of various sizes to define how well the flow requirements presented in Table VIII-3 were met.

Based on this analysis it is estimated that an effective storage of 19,000 acre-feet will be needed at the alternate Rockfish Creek site or 10,800 acre-feet at the proposed Faison site for flow regulation in the Northeast Cape Fear River.

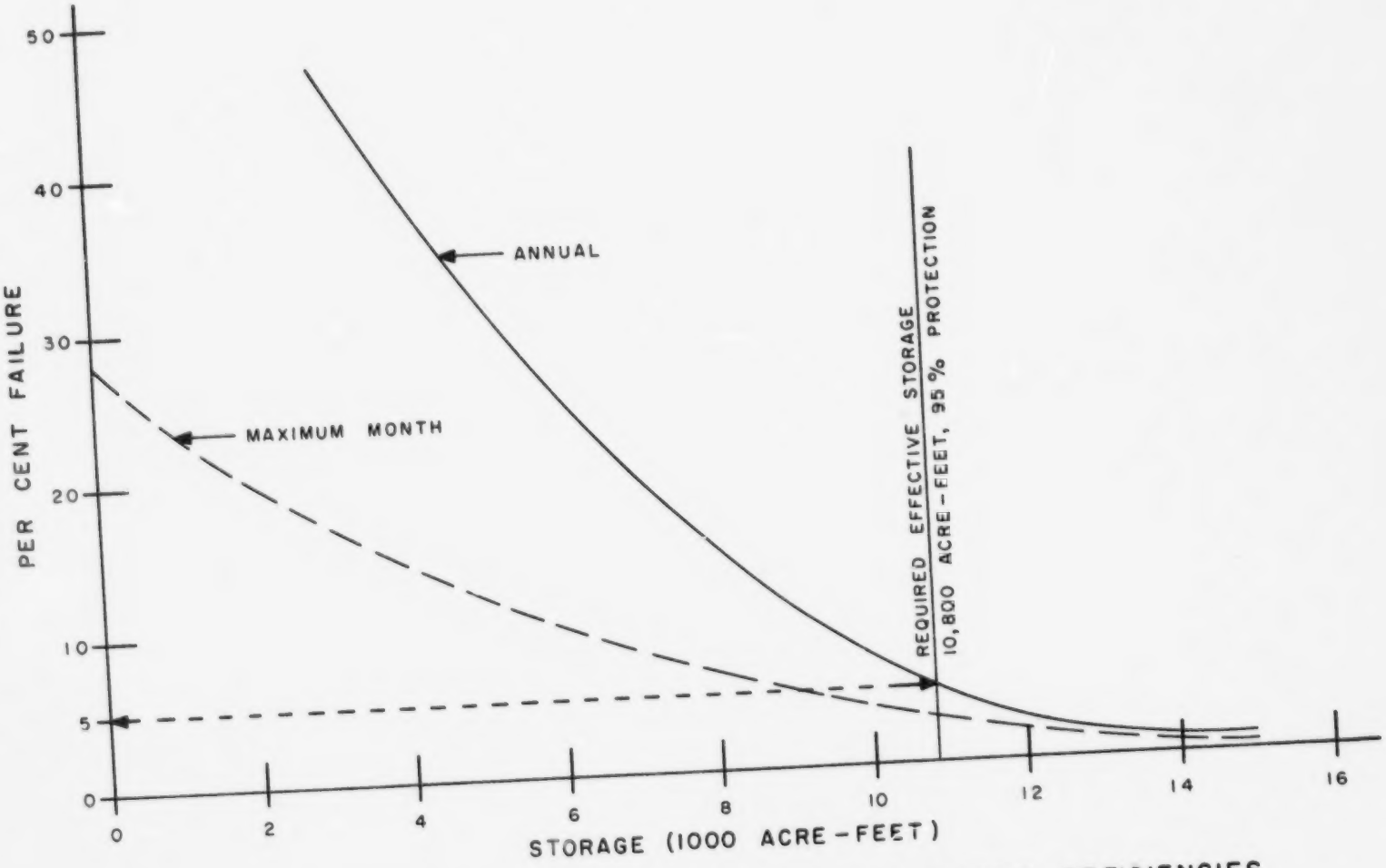
The effective storage was selected based on meeting the streamflow requirements for water quality control 95 percent of the years. This assurance level is commonly used in this area for protecting recreation, sport and commercial fishing interest. The percent of expected failures to occur annually and for the month with the greatest number of deficiencies are plotted against storage in Figure VIII-2 for the Faison site.

With the provision of 10,800 acre-feet of effective storage, it can be expected that failures will occur in no more than 5 percent of the years with no single month failing to meet the required monthly flow in more than 2.5 percent of the years.

Table VIII-4 indicates the percent of the years for a series of reservoir sizes that the available reservoir releases, plus unregulated flows were less than the monthly flows required for maintaining the water quality objectives. The data presented is for the Faison site and water quality needs for the year 2025.

Table VIII-3
REQUIRED STREAMFLOW FOR WATER QUALITY CONTROL NORTHEAST CAPE FEAR RIVER AT CONFLUENCE WITH ROCKFISH CREEK
(cfs)

Month	Year			
	1975	1985	2000	2025
January	10	18	20	25
February	10	23	25	30
March	10	33	35	40
April	15	38	40	50
May	25	50	55	65
June	35	60	65	75
July	50	69	75	90
August	50	69	75	90
September	50	69	75	90
October	20	48	55	65
November	10	33	40	50
December	10	18	20	25



PER CENT FAILURE OF ANNUAL & MAXIMUM MONTHLY DEFICIENCIES
VS
STORAGE REQUIREMENTS FAISON SITE FOR YEAR 2025

FIGURE VIII - 2

Table VIII-4
PROBABILITY OF STREAMFLOW DEFICITS IN THE NORTHEAST CAPE FEAR RIVER AT WALLACE IN 2025 FOR SELECTED FLOW REGULATION STORAGE

Month	Required Streamflow for Quality Control cfs	Percent of Time Releases and Unregulated Flow Less than Required Flow			
		Faison Reservoir Storage			
		0.1 A.F.	5,000 A.F.	10,000 A.F.	15,000 A.F.
January	25	0.4	0	0	0
February	30	3.4	0	0	0
March	40	0.2	0	0	0
April	50	5.2	0	0	0
May	65	20.2	0.4	0	0
June	75	27.6	5.8	0	0
July	90	23.4	11.8	1.6	0
August	90	26.0	10.2	1.8	0.6
September	90	24.2	13.4	4.2	0.6
October	65	20.8	3.8	1.8	0.2
November	50	19.2	3.4	0.6	0.2
December	25	6.4	0.2	0.2	0

To provide the storage for flow regulation through 2025 a storage reservoir containing 10,800 acre-feet for flow augmentation storage and 7,000 acre-feet for sedimentation and evaporation would be required at the Faison site. The total storage of 17,800 acre-feet is within the capabilities of the Kornegay or the Faison site. The year of first need for flow augmentation was determined to occur in 1975.

Streamflows shown in Tables VIII-2 and VIII-3 for Rockfish Creek and the Northeast Cape Fear River are the required flows in the critical reaches below Wallace. It should be noted that in both watersheds proposed reservoirs are located some distance upstream from use points. Significant proportions of streamflow in the critical reaches will be contributed by the uncontrolled drainage areas. This was considered in evaluating the storage requirements. Therefore, the table of flow requirements should not be interpreted as a reservoir release schedule. Water quality releases should be made on the basis of stream needs as determined by the responsible water pollution control agency from data obtained through water quality monitors.

Proposed reservoir sites will contain large areas of swampland and significant amounts of organic materials may remain after the reservoir areas have been cleared of trees. This organic material may significantly affect water quality in the lower strata of the reservoir.[6] Therefore, outlet works should be designed to permit release of high quality water at all times. The discharge of low quality water from the reservoir

would require a larger flow to adequately assimilate wastes in critical reaches. The bottom water containing low dissolved oxygen and high BOD should be discharged only when uncontrolled flow downstream will adequately assimilate the BOD and or oxygen deficient water. Appropriate equipment should be installed downstream from the reservoir to monitor stream quality and reservoir releases.

As has been discussed previously, the provision of secondary treatment for municipal wastes from the City of Wilmington and equivalent treatment for all industrial wastes in the area will greatly improve water quality in the adjacent watercourses. But since Smith Creek, the Northeast Cape Fear River and the Cape Fear River are all affected by tidal action in the Wilmington area, the extent of quality improvement cannot be evaluated without an extensive estuarine survey. Residual waste loads from upstream industrial discharges to the Cape Fear River also produce significant effects on estuary water quality. Several reservoirs have been proposed or authorized for construction on the Upper Cape Fear River. 11,12,13 Each of these reservoirs could contain flow regulation storage and could produce significant beneficial effects on low flows reaching the estuary. An accurate evaluation of waste treatment and flow regulation needs at Wilmington for protection of water quality in the greater Cape Fear River estuary can only be made after a detailed and comprehensive study of the entire Cape Fear River basin.

Waste load estimates and their companion water quality and flow regulation requirements are based on the best economic data available. However, in a basin of this size, significant variations in population and industrial growth from those projected for a larger study area may occur. Therefore, the flow regulation needs of the basin should be carefully reevaluated at the time of construction of proposed flow regulation reservoirs and, if necessary, appropriate adjustments made.

IX. BENEFITS

The benefits attributable to water quality control may be defined as the increase in the value of goods or services which results from water quality control measures as compared with the conditions that would result without quality control. The benefits include tangibles and intangibles which may be differentiated as those benefits that can be expressed in monetary terms and those that are recognized as having real value in satisfying human needs but are not fully measurable in monetary terms.

The value of the benefits may be determined by assessing the damages in the absence of water quality control such as preclusion of economic activities, loss of recreational opportunities, increased municipal and industrial water treatment costs, loss of industrial production, impairment of health and welfare, damage to fish and wildlife, and degradation of esthetics.

The significant damages that would result in the Northeast Cape Fear in the absence of water quality control are, degradation of esthetics, loss of recreational opportunity, and damage to fish and wildlife.

The value of fish and wildlife benefits for the Northeast Cape Fear River from its confluence with Rockfish Creek to a point 30 miles downstream was evaluated by the U. S. Bureau of Sport Fisheries and Wildlife. The average annual value for sport fishing was determined to be $23,800 and represent 26,500 annual fisherman man days. The average annual value for commercial fishing was evaluated at $6,100.

Information concerning the value of recreational man days which could be attributed to the main stem of the Northeast Cape Fear, was not available. An indication of the potential beneficiaries in the area may be related to the population of the basin, which is expected to reach 140,000 in 1975. and increase to 165,000 in 2025. Also a preliminary estimate of recreation attendance at the proposed reservoirs shows a potential of 50,000 recreation man days in 1995.

Sufficient data were not available to evaluate directly all the economic effects of the water quality improvements; therefore, the approximate value of the benefits was determined by estimating the cost of achieving the same results by the most likely alternative. The evaluation of the alternates is discussed in the following paragraphs.

Flow requirements for Rockfish Creek and the Northeast Cape Fear were determined in Chapter VIII. These flow requirements can be met by providing storage in one or two single purpose reservoirs. Either the proposed Faison or Kornegay reservoir

site could be utilized for a single purpose reservoir to provide the 17,800 acre-feet of storage as determined in Chapter VIII for flow regulation in the Northeast Cape Fear River. Construction cost of the reservoir is estimated at $1,700,000. Average annual cost is estimated at $75,000 including maintenance and capital amortization at 3 1/8 percent.

The above reservoir location cannot provide flow regulation in Rockfish Creek. Therefore, the construction of a single purpose reservoir on Rockfish Creek to provide flow regulation for the critical reaches of both streams was investigated. The relative location of this reservoir and stream reaches is shown in Figure VIII-1.

The reservoir located on the Rockfish site discussed in Chapter VIII would contain 19,000 acre-feet of flow regulation storage and 9,000 acre-feet of evaporation and sedimentation storage for a total of 28,000 acre-feet. Reservoir construction costs are estimated to be $2,800,000 at this site. Average annual costs including maintenance and capital amortization are estimated at $141,000. Intangible benefits resulting from improved water quality and stabilization of water levels in the Northeast Cape Fear above the confluence with Rockfish Creek would not result from the Rockfish reservoir.

In addition to flow regulation, other methods of water quality control applicable to the basin were investigated. These methods include advanced waste treatment and stream aeration.

Various methods of advanced waste treatment have been developed for removal of very high precentages of pollutants from waste flows. The majority of these methods has not progressed beyond laboratory or pilot scale plants. One method, the carbon adsorption process has been proven effective in full scale operation and was considered for application to the present case.[15]

Carbon adsorption units are usually preceded by standard secondary treatment followed by lime alum coagulation-sedimentation and sand filtration. Well-operated secondary treatment plants may be expected to achieve 90 percent BOD removal, coagulation-sedimentation, an additional 3 percent removal, and carbon adsorption, an additional 6 percent removal for a total BOD removal efficiency of 99 percent.[16]

An advanced waste treatment plant located near the confluence of Rockfish Creek and Little Rockfish Creek to treat effluents from the Wallace and J. P. Stevens treatment plants would adequately

protect water quality in Rockfish Creek and the Northeast Cape Fear River. The plant would be required to obtain 92 percent BOD removal from a waste flow of 4.0 mgd in 1975, 94 percent removal from 6.1 mgd in 2000, and 95 percent removal from 7.1 mgd in 2025. The required removal efficiencies could be effected by construction of a 6 mgd coagulation-sedimentation facility in 1975, and the addition of a 3 mgd carbon adsorption unit in 2000. Advanced treatment would be required only during low flow periods when stream assimilative capacities are reduced below that necessary for assimilation of residual waste loads after secondary treatment. It is estimated that a total of 300 million gallons (mg) would be treated in 1975, 500 mg in 1985, 600 mg in 2000, and 840 mg in 2025.

Capital costs of the coagulation-sedimentation unit and carbon adsorption unit are estimated to be $900,000 and $435,000 respectively.[15] Construction of pipelines required to convey effluent from the existing treatment facilities to the advanced treatment plan would cost an additional $150,000. The average annual cost of advanced waste treatment including operation, maintenance and capital amortization at 3 1/8 percent is estimated to be $118,000.

Although advanced waste treatment would achieve the established quality objectives, the intangible benefits would be somewhat less than those gained by flow regulation. As streamflow would not be increased, improvement in water quality produced by dilution of natural pollution would not occur and maintenance of water levels would be eliminated in the Northeast Cape Fear River.

Water quality may also be protected or improved by increasing the assimilative capacity of a stream. One method of increasing the assimilative capacity of a stream, which is considered technically feasible, but has not yet been significantly utilized on flowing streams, is mechanical aeration.[17] Mechanical aeration is widely used in various waste treatment processes and in aerated waste stabilization lagoons. Laboratory studies indicate aeration may be effectively used to increase the assimilative capacity of flowing streams by increasing the supply of dissolved oxygen.[18]

Available information indicates the most effective application of aeration may be made by locating float mounted aerators at intervals along a stream. Each aerator would be designed to increase dissolved oxygen in the stream 1 mg/l and spaced at an interval which would prevent dissolved oxygen from falling below established objectives between aerators. Calculations indicated

that three aerators of two horsepower each spaced approximately 1.2 miles apart with the upstream aerator at the mouth of Little Rockfish Creek would maintain minimum dissolved oxygen of 3.0 mg/l in Rockfish Creek. A total of five aerators of ten horsepower each spaced at varying intervals along a 24-mile reach would be required for maintenance of minimum dissolved oxygen of 4.0 mg/l in the Northeast Cape Fear River.

A preliminary design of a facility was prepared including aerator, float, anchorages, electrical service, and access roads. The capital cost of a two horsepower aerator installation for Rockfish Creek based on the preliminary design and construction costs of similar aeration installations in waste treatment facilities was estimated to be $20,850. The average annual cost for three aerator installations including labor, maintenance, capital amortization at 3 1/8 percent and operating costs was estimated at $10,750. This estimate was based on 10-year equipment life, and an average of 75 days per year operation in 1975, 100 days per year in 2000 and 120 days per year in 2025.

Capital costs of the ten horsepower installations on the Northeast Cape Fear were estimated to be $25,000 each. The estimated average annual cost of aeration in the Northeast Cape Fear is $18,300, including operation, maintenance, and amortization at 3 1/8 percent.

Increasing stream assimilative capacity through mechanical aeration has several significant advantages. Aeration is only required when decreasing streamflow reduced assimilative capacity below that required by existing waste loads. For Rockfish Creek, aeration would be required only 20 percent of the time in 1975, 27 percent in 2000, and 33 percent in 2025. Even less operation would be required on the Northeast Cape Fear. Thus, operating costs are reduced by part-time operation.

Aerator installations are relatively simple and require a minimum of skilled personnel for operation and maintenance. The required labor may usually be obtained locally. Also, aerator installations are comparatively low in initial cost. Thus, the part-time operation of the aerators does not result in large amounts of capital being tied up for equipment on standby operation.

Aeration as the primary method of quality control also has several disadvantages. Should increased runoff flush the heavily loaded flow downstream as a "slug", dissolved oxygen would be rapidly depleted in a reach without aeration. In the lower reach of Rockfish Creek this type of problem should not

be of significance as the "slug" would be flushed into the Northeast Cape Fear River where the larger streamflow would reduce the effects of degradation. However, in the Northeast Cape Fear River, flushing the heavy residual waste load downstream to non-aerated reaches during increased streamflow could result in adverse depletion of dissolved oxygen levels and possible fish kills.

Several other inherent disadvantages of aeration become significant in the case of the Northeast Cape Fear. In a stream of this size it is very difficult to determine the most optimum locations for aerators. For different flow conditions, critical dissolved oxygen levels may occur at points other than the aerator locations. The location of the aerators within the stream would create a hazard to small boats which presently travel the river for fishing and recreation. Also, as streamflow would not be increased, improvement in water quality produced by dilution of natural pollution would not occur.

The above disadvantages of aeration were considered very significant with respect to the Northeast Cape Fear River, and the method was not considered adequate protection of water quality for all purposes. However, for the critical reach of Rockfish Creek, the disadvantages were not considered significant, and aeration was considered a feasible method of water quality control.

The feasibility of aeration for water quality control in Rockfish Creek was the basis for the last control method considered; that of combining aeration and flow regulation. Water quality could be adequately protected in both critical reaches and almost all flow regulation benefits previously discussed obtained by providing aeration of Rockfish Creek, and flow regulation in the Northeast Cape Fear. The total capital costs for this system are estimated at $1,762,500, and average annual cost at $85,800.

The relative values of advantages and disadvantages of the water quality control measures considered and their estimated costs were carefully examined. The comparative costs of the various methods considered are shown in Table IX-1. An evaluation of piping the wastes from the Rockfish Creek watershed to the Northeast Cape Fear River was made but not included in Table IX-1 as the cost exceeded that of providing aeration for Rockfish Creek.

TABLE IX-1

COMPARATIVE COSTS OF FEASIBLE WATER QUALITY CONTROL METHODS

Method	Capital Cost	Annual Cost
1. Flow Regulation		
Single purpose reservoir at Rockfish Creek Site	$2,800,000	$141,000
2. Advanced Waste Treatment	1,485,000	118,000
3. Mechanical Aeration		
Aeration of Rockfish Creek	62,500	10,800
4. Aeration plus Flow Regulation		
a. Aeration of Rockfish Creek	62,500	10,800
b. Single purpose reservoir at Faison or Kornegay Site	1,700,000	75,000
TOTAL COST NO. 4	$1,762,500	$ 85,800

The value of annual benefits for flow regulation in the Northeast Cape Fear River is equal to the cost of the most feasible alternate which is a single purpose reservoir at the Faison or Kornegay site. The annual value of benefits for the Northeast Cape Fear River is $75,000.

The above value of benefits is based upon the maintenance of good quality dilution water in stream reaches above waste sources. Therefore, provisions should be made in the design and construction of all reservoirs to insure that swamp vegetation remaining after clearing operations will not significantly deteriorate reservoir water quality and that outlet works provide maximum flexibility for release of water high in dissolved oxygen.[6]

The benefits to be derived from water quality control will be distributed along approximately 30 miles of the Northeast Cape Fear River. The benefits are widespread in scope and appear sufficient in magnitude to warrant the provision of the required volume of storage for flow regulation. The primary beneficaries are recreationist, sport and commercial fisherman of the basin and surrounding counties.

APPENDICES

APPENDIX A

Water Quality Data - Northeast Cape Fear River Basin

North Carolina State Stream Sanitation Committee Pollution Survey 1955-56

Northeast Cape Fear River at Head of Kornegay Reservoir — Drainage Area (sq. mi.) 30.5

Date Collected	Discharge cfs	Temp °C	Color ppm	Turbidity ppm	pH	Hardness as $CaCO_3$ ppm	Chloride ppm	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	5-Day B.O.D. ppm	5-Day B.O.D. lbs/day	Coliform M.P.N. per 100 ml.
1955												
8-5	7.0	25	420	60	6.6	41	160	0.0	00	9.8	460	300,000
8-30	85	25	320	6	5.5	22	42	2.5	30	3.5	2,000	15,000
10-5	50	20	340	3	5.6	43	37	2.4	26	1.9	640	4,300
10-10	58	19	360	2	5.8	28	34	2.8	30	1.9	740	1,500
10-18	40	15	280	8	6.5	37	52	4.8	47	8.2	2,200	4,300
10-20	37	15	240	5	6.5	15	44	4.9	49	2.3	570	7,300
1956												
8-23	59	23	160	3	5.3	18	57	4.4	51	1.5	600	39,000
Northeast Cape Fear River at Kornegay Dam Site — Drainage area (sq. mi.) 115												
1955												
7-14	285	24	260	15	5.4	24	17	3.3	39	0.9	1,700	7,300
9-27	345	20	440	3	5.2	24	10	1.9	21	2.5	5,800	4,300
10-11	145	17	360	6	5.4	19	20	3.4	35	1.6	1,600	1,100
10-24	82	19	280	5	5.7	18	18	5.0	53	1.6	890	2,400
11-2	75	10	320	3	5.8	15	24	6.3	56	1.0	510	4,300
Goshen Swamp at Head of Faison Reservoir — Drainage area (sq. mi.) 65.5												
1955												
7-14	-	25	160	15	5.6	20	25	4.3	51	0.8	-	910
9-27	102	20	400	15	5.9	22	17	3.1	34	2.0	1,400	9,300

Appendix A (Continued)

Date Collected	Discharge cfs	Temp °C	Color ppm	Turbidity ppm	pH	Hardness as $CaCO_3$ ppm	Chloride ppm	Dissolved Oxygen ppm	Dissolved Oxygen %Sat	5-Day B.O.D. ppm	5-Day B.O.D. lbs/day	Coliform M.P.N. per 100 ml.
Goshen Swamp at head of Faison Reservoir (continued)												
1955												
10-11	35	16	320	10	6.2	30	28	4.0	40	1.5	350	24,000
10-24	17	20	240	8	6.2	26	49	5.5	60	1.9	220	4,300
11-2	19	11	280	10	6.3	24	37	6.3	57	1.9	240	9,300
Northeast Cape Fear River at Chinquapin										**Drainage Area (sq. mi.)**		600
1955												
7-14	628	25	180	15	5.8	24	14	5.5	65	1.3	5,500	15,000
9-27	3,850	22	400	3	5.7	17	6	2.6	30	1.8	47,000	2,400
10-18	342	16	240	30	6.6	25	12	7.1	71	2.2	5,100	7,300
11-2	374	11	240	6	6.5	30	12	8.5	77	1.2	3,000	24,000
11-8	302	11	90	10	6.5	23	15	9.3	84	1.0	2,000	2,400
1956												
7-12	117	25	170	3	6.8	29	19	6.4	76	2.5	2,000	2,300
Rockfish Creek above Wallace										**Drainage Area (sq. mi.)**		122
1955												
7-14	14	26	100	15	6.4	22	5	5.6	68	0.5	47	360
9-29	150	22	360	2	5.4	21	7	3.9	44	1.2	1,200	43,000
10-18	33	14	230	8	6.5	26	7	7.6	73	1.5	330	4,300
10-28	20	13	210	15	6.5	27	7	7.9	75	1.8	240	1,500
10-31	33	15	230	20	6.6	30	8	6.9	68	6.0	1,300	93,000
1956												
7-12	4.4	24	160	10	6.9	29	7	3.9	46	1.7	50	930

Appendix A (Continued)

Date Collected	Discharge cfs	Temp °C	Color ppm	Turbidity ppm	pH	Hardness as $CaCO_3$ ppm	Chloride ppm	Dissolved Oxygen ppm	Dissolved Oxygen %Sat	5-Day B.O.D ppm	5-Day B.O.D lbs/day	Coliform M.P.N. per 100 ml.
Rockfish Creek below Little Rockfish Creek											Drainage Area (sq. mi.) 165	
1955												
9-29	210	23	340	2	6.1	7	8	2.4	28	1.7	2,400	24,000
10-18	45	15	240	15	6.7	29	11	6.9	68	1.0	300	30,000
10-28	25	14	200	10	6.8	35	10	6.3	61	4.2	710	43,000
10-31	147	16	270	30	6.5	24	10	6.5	65	2.7	2,700	43,000
1956												
7-1	60	25	-	-	7.0	-	11	5.6	67	-	-	-
7-12	9	26	130	15	7.0	50	26	5.7	70	5.1	310	4,300
7-20	21	25	160	15	6.7	26	14	4.5	54	2.6	370	93,000
7-31	29	25	180	3	6.8	36	8	5.7	68	1.6	310	75,000
Rockfish Creek at Confluence with Northeast Cape Fear River											Drainage Area (sq. mi.) 169	
1956												
7-1	60	27	-	-	7.2	-	11	4.5	56	-	-	-
7-12	9.2	27	90	3	6.5	41	11	8.0	99	3.4	210	2,300
7-20	22	25	140	8	6.8	28	7	3.6	43	2.4	360	23,000
7-31	30	26	180	3	6.8	32	8	5.5	67	2.6	530	93,000
Northeast Cape Fear River near Holly Shelter Swamp (Tidal Limits)											Drainage Area (sq. mi.) 920	
1955												
7-28	450	30	240	10	6.7	30	12	4.1	54	1.3	4,000	-
8-5	450	28	320	40	6.4	36	10	4.5	57	0.6	1,800	930
8-18	6,000	25	280	6	5.6	30	5	3.0	36	2.4	97,000	4,300
9-14	3,300	23	340	3	5.8	32	12	2.5	29	1.3	29,000	430
9-27	6,000	24	320	2	5.7	17	3	1.8	21	2.3	93,000	2,400
10-17	500	18	260	5	6.6	27	13	5.8	61	2.6	8,000	230

Appendix A (Continued)

Date Collected	Discharge cfs	Temp °C	Color ppm	Turbidity ppm	pH	Hardness as $CaCO_3$ ppm	Chloride ppm	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	5-Day B.O.D. ppm	5-Day B.O.D. lbs/day	Coliform M.P.N. per 100 ml.
Northeast Cape Fear River near Holly Shelter Swamp (Tidal Limits) (continued)												
1956												
7-12	110	29	180	3	6.7	31	15	4.6	59	4.4	3,300	930
Northeast Cape Fear River near Castle Hayne (Tidal)									Drainage Area (sq. mi.)			1,500
1955												
7-28	580	30	210	8	6.1	13	13	2.3	30	1.3	5,100	-
8-5	460	29	290	15	6.2	30	10	2.3	29	1.8	5,600	7,000
8-18	9,700	26	340	6	5.6	18	8	2.5	30	1.8	120,000	7,000
8-30	7,300	27	440	3	5.7	21	7	1.1	14	1.3	64,000	36
9-14	7,200	23	420	3	5.6	19	10	1.3	15	1.4	68,000	2,300
9-27	11,000	23	360	3	5.5	16	4	1.7	20	1.7	130,000	2,500
10-17	1,200	16	360	6	6.3	29	10	1.8	18	1.9	15,000	2,100

APPENDIX B
MUNICIPAL AND INDUSTRIAL WASTE DISCHARGES
NORTHEAST CAPE FEAR RIVER BASIN

Source of Wastes	Estimated Population Served	Avg. Daily Flow M.G.D.	Population Equivalent Discharged	Degree of Treatment	Receiving Stream
Beulahville	950	0.100	145	Stab. Lagoons	Unnamed trib. to Muddy Creek
Burgaw	1,800	0.131	1,260	Primary	Osgood Canal to Burgaw Creek
Carolina Nitrogen Corp. Wilmington - Industrial Waste	-	0.190	-	Holding Pond Blending	Northeast Cape Fear River
Domestic Sewage				Septic Tanks Subsurface Disposal	
Charles F. Cates & Sons Faison	-	0.001	-	Secondary	Unnamed trib. to Goshen Swamp
Faison	635	0.070	-	Primary	Reedy Branch to Goshen Swamp
Mobill Textiles, Inc. Wilmington	-	-	-	Lagoon	Smith Creek
Mt. Olive	3,600	0.387	462	Secondary	Northeast Cape Fear River
Mt. Olive Pickle Co.	-	0.110	2,700	Secondary	Barlow Branch
Pender Packing Co Rocky Point	-	0.001	765	Grease Removal Some blood recovery	Morgan Creek
Rooks Packing Company Rocky Point	-	0.003	618	None	Rileys Creek

Source of Wastes	Estimated Population Served	Av. Daily Flow M.G.D.	Population Equivalent Discharged	Degree of Treatment	Receiving Stream
Rose Hill	900	0.100	225	Secondary	Bland Branch to Island Creek
Rose Hill Poultry Co.	-	0.440	1,980	Stab. Lagoons	Cabin Branch to Beaverdam Br.
Stevens, J.P. Co., Inc. Wallace	-	2.200	8,200	Secondary	Little Rockfish Creek
Swift & Company Wilmington	-	Septic Trank - Subsurface disposal - None for industrial Waste			
Tar Heel Foods Co., Inc. Wilmington	-	0.145	-	Secondary	Smiths Creek
Timme Corporation Wilmington	-	0.050	936	Secondary Extended Aeration	Smith Creek
Wallace	2,200	0.329	330	Secondary	Rockfish Creek
Wanet Sausage Co. Wilmington	-	26,000 to 36,000 gal/wk.	78	Stab. Lagoon	Smith Creek
Wilmington	44,700	4.500	44,700	None	Smith Creek, Northeast Cape Fear River, and Cape Fear River

APPENDIX C

Classification and Water Quality Standards Applicable to Surface Waters of North Carolina as Adopted by the State Stream Sanitation Committee

CLASS A-I

Best Usage of Waters: Source of water supply for drinking, culinary, or food-processing purposes or any other usage requiring water of lower quality.

Conditions Related to Best Usage: This class is intended primarily for waters having watersheds which are uninhabited and otherwise protected as required by the State Board of Health and which require only approved disinfection, with additional treatment when necessary to remove naturally present impurities, in order to meet the "Public Health Service Drinking Water Standards" and will be considered safe for drinking, culinary, and food-processing purposes.

Quality Standards for Class A-I Waters

1. Floating solids; settleable solids; sludge deposits; tastes or odor-producing substances.

None attributable to sewage, industrial wastes or other wastes.

2. Sewage, industrial wastes, or other wastes.

None

3. Toxic wastes; oils; deleterious substances; colored or other wastes.

None

CLASS A-II

Best Usage of Waters: Source of water supply for drinking, culinary or food-processing purposes and any other best usage requiring waters of lower quality.

Conditions Related to Best Usage: The waters, if subjected to approved treatment equal to coagulation, sedimentation, filtration and disinfection, with additional treatment if necessary to remove naturally present impurities, will meet the "Public Health Service Drinking Water Standards" and will be considered safe for drinking, culinary or food-processing purposes.

Quality Standards for Class A-[illegible] Waters

1. Floating oil[illegible]; settleable solids; sludge deposits.

Only such amount attributable to sewage, industrial wastes or other wastes as will not, after reasonable opportunity for dilution and mixture of same with the receiving waters, make the waters unsafe or unsuitable as a source of water supply for drinking, culinary, or food-processing purposes, injurious to fish and wildlife, or impair the waters for any other best usage established for this class.

2. Sewage, industrial wastes or other wastes.

None which are not effectively treated to the satisfaction of the Committee and in accordance with the requirements of the State Board of Health.

3. Odor-producing substances contained in sewage, industrial wastes, or other wastes.

Only such amounts, whether alone or in combination with other substances or wastes, as will not, after reasonable opportunity for dilution and mixture of same with the receiving waters, cause taste and odor difficulties in water supplies which cannot be corrected by treatment as specified under "Conditions Related to Best Usage," impair the palatability of fish or have a deleterious effect upon any best usage established for waters of this class.

4. Phenolic compounds.

Not greater than 3.[illegible] parts per billion (phenols).

5. pH

Shall be normal for the waters in the area, which generally shall range between 6.0 and 8.5 except that swamp waters may have a low of 4.3.

6. Total hardness.

Not greater than 100 parts per million as $CaCO_3$.

7. Dissolved oxygen.

Not less than 5.0 parts per million for trout producing waters; not less than 4.0 parts per million for non-trout waters except that swamp waters may have a minimum of 3.0 parts per million.

8. Toxic wastes; oils; deleterious substances; colored or other wastes; or heated liquids.

Only such amounts, whether alone or in combination with other substances or wastes, and only such temperatures as

will not render the waters unsafe or unsuitable as a source of water supply for drinking, culinary, or food-processing purposes, injurious to fish and wildlife or adversely affect the palatability of same, or impair the waters for any other best usage established for this class.

CLASS B

Best Usage of Waters: Bathing and any other usage except as source of water supply for drinking, culinary or food-processing purposes.

Conditions Related to Best Usage: The waters, under proper sanitary supervision by the controlling health authorities, will meet accepted standards of water quality for outdoor bathing places and will be considered safe and satisfactory for bathing purposes. Also, suitable for other uses requiring waters of lower quality.

Quality Standards for Class B Waters

1. Floating solids; settleable solids; sludge deposits.

Only such amounts attributable to sewage, industrial wastes or other wastes as will not, after reasonable opportunity for dilution and mixture of same with the receiving waters, make the waters unsafe or unsuitable for bathing, injurious to fish and wildlife, or impair the waters for any other best usage established for this class.

2. Sewage, industrial wastes, or other wastes.

None which are not effectively treated to the satisfaction of the Committee. In determining the degree of treatment required for such waste when discharged into waters to be used for bathing, the Committee will take into consideration the quantity and quality of the sewage and wastes involved and the proximity of such discharges to the waters in this class.

3. Phenolic compounds.

Not to exceed 3.0 parts per billion (phenols).

4. pH

Shall be normal for the waters in the area, which generally shall range between 6.0 and 8.5, except that swamp waters may have a low of 4.3.

5. Dissolved oxygen.

Not less than 5.0 parts per million for trout producing waters; not less than 4.0 parts per million for non-trout waters, except that swamp waters may have a minimum of 3.0 parts per million.

6. Toxic wastes; oils; deleterious substances; colored or other wastes; or heated liquids.

Only such amounts, whether alone or in combination with other substances or wastes, and only such temperatures as will not render the waters unsafe or unsuitable for bathing, injurious to fish and wildlife or adversely affect the palatability of same, or impair the waters for any other best usage established for this class.

CLASS C

Best Usage of Waters: Fishing and any other usage except for bathing or as a source of water supply for drinking, culinary or food-processing purposes.

Conditions Related to Best Usage: The waters will be suitable for fish and wildlife propagation. Also, suitable for other uses requiring waters of lower quality.

Quality Standards for Class C Waters

1. Floating solids; settleable solids; sludge deposits.

Only such amounts attributable to sewage, industrial wastes or other wastes as will not, after reasonable opportunity for dilution and mixture of same with the receiving waters, make the waters unsafe or unsuitable for fish and wildlife, or impair the waters for any other best usage established for this class.

2. pH

Shall be normal for the waters in the area, which generally shall range between 6.0 and 8.5, except that swamp waters may have a low of 4.3.

3. Dissolved oxygen.

Not less than 5.0 parts per million for trout producing waters; not less than 4.0 parts per million for non-trout waters, except that swamp waters may have a minimum of 3.0 parts per million.

4. Toxic wastes; oils; deleterious substances; colored or other wastes; or heated liquids.

Only such amounts, whether alone or in combination with other substances or wastes, and only such temperatures as will not render the waters injurious to fish and wildlife or adversely affect the palatability of same, or impair the waters for any other best usage established for this class.

CLASS D

Best Usage of Waters: Agriculture, industrial cooling and process water supply, fish survival and any other usage, except fishing, bathing or as source of water supply for drinking, culinary or food-processing purposes.

Conditions Related to Best Usage: The waters without treatment and except for natural impurities which may be present therein will be suitable for agricultural uses and will permit fish survival. The waters will also be usable after special treatment by the user as may be needed under each particular circumstance for industrial purposes, including cooling and process waters.

Quality Standards for Class D Waters

1. Floating solids, settleable solids; sludge deposits.

Only such amounts attributable to sewage, industrial wastes or other wastes as will not, after reasonable opportunity for dilution and mixture of same with the receiving waters, render the waters unsuitable for agriculture, industrial cooling purposes and fish survival.

2. pH

Shall be normal for the waters in the area, which generally shall range between 6.0 and 8.5, except that swamp waters may have a low of 4.3.

3. Dissolved oxygen.

Not less than 3.0 parts per million.

4. Toxic wastes; oils; deleterious substances; colored or other wastes; or heated liquids.

Only such amounts attributable to sewage, industrial wastes or other wastes and only such temperatures as will not render the waters unsuitable for agriculture, industrial cooling purposes and fish survival.

CLASS E

Best Usage of Waters: Navigation and disposal of sewage, industrial wastes, or other wastes, and any other uses except agriculture, source of industrial cooling waters, fishing, bathing, or source of water supply for drinking, culinary or food-processing purposes.

Conditions Related to Best Usage: Waters will be suitable for navigation where navigable waters are involved, and may be used for waste disposal to the extent that the stream will accommodate same within the limits of the prescribed specifications for

this class. This class will not be assigned to waters which can, in the light of consideration prescribed by the Statutes, be properly assigned to a higher class.

Quality Standards for Class E Waters

1. Floating solids; settleable solids; oils; sludge deposits.

Only such amounts attributable to sewage, industrial wastes or other wastes as will not interfere with navigation in navigable waters, and will not create an offensive condition in waters, whether or not navigable.

2. pH

Not lower than 4.3 in waters used for navigation. Otherwise, it shall be maintained at such levels as not to adversely affect the quality of waters in any other class to which these waters may be tributary.

3. Dissolved oxygen.

Sufficient to prevent the development of an offensive condition.

4. Odor-producing substances.

Only such amounts as will not create an offensive condition.

CLASS SA

Best Usage of Waters: Shellfishing for market purposes and any other usage requiring waters of lower quality.

Conditions Related to Best Usage: Waters will meet the sanitary and bacteriological standards given in the latest edition of "Manual of Recommended Practices for Sanitary Control of the Shellfish Industry," recommended by the Public Health Service and will be considered safe and suitable for shellfish culture.

Quality Standards for Class SA Waters

1. Floating solids; settleable solids; sludge deposits.

None attributable to sewage, industrial wastes or other wastes.

2. Sewage, industrial wastes, or other wastes.

None which are not effectively treated to the satisfaction of the Committee and in accordance with the requirements of the State Board of Health.

3. pH

Range between 6.8 and 8.5.

4. Dissolved oxygen.

Not less than 4.0 parts per million, except that swamp waters may have a minimum of 3.0 parts per million.

5. Toxic wastes; oils; deleterious substances; colored or other wastes; or heated liquids.

Only such amounts, whether alone or in combination with other substances or wastes, and only such temperatures as will not make the waters unsafe or unsuitable for fish and shellfish or their propagation, impair the palatability of same, or impair the waters for any other best usage established for this class.

6. Organisms of coliform group.

The coliform bacterial content of the water shall not exceed the limits specified in the latest edition of "Manual of Recommended Practices for Sanitary Control of the Shellfish Industry," recommended by the Public Health Service.

CLASS SB

Best Usage of Waters: Bathing and any other usage except shellfishing for market purposes.

Conditions Related to Best Usage: The waters, under proper sanitary supervision by the controlling health authorities, will meet accepted sanitary standards of water quality for outdoor bathing places and will be considered safe and satisfactory for bathing purposes.

Quality Standards for Class SB Waters

1. Floating solids; settleable solids; sludge deposits.

None attributable to sewage, industrial wastes or other wastes.

2. Sewage, industrial wastes, or other wastes.

None which are not effectively treated to the satisfaction of the Committee. In determining the degree of treatment required for such wastes when discharged into waters to be used for bathing, the Committee will take into consideration the quantity and quality of the sewage and wastes involved and the proximity of such discharges to the waters in this class.

C-3

3. pH

Shall be normal for the waters in the area, which generally shall range between 6.0 and 8.5, except that swamp waters may have a low of 4.3.

4. Dissolved oxygen.

Not less than 4.0 parts per million, except that swamp waters may have a minimum of 3.0 parts per million.

5. Toxic wastes, oils, deleterious substances; colored or other wastes; or heated liquids.

Only such amounts, whether alone or in combination with other substances or wastes, and only such temperatures as will not make the waters unsafe or unsuitable for bathing, injurious to fish or shellfish, or adversely affect the palatability of same, or impair the waters for any other best usage established for this class.

CLASS SC

Best Usage of Waters: Fishing, and any other usage except bathing or shellfishing for market purposes.

Conditions Related to Best Usage: The waters will be suitable for fishing and fish propagation. Also, suitable for other uses requiring waters of lower quality.

Quality Standards for Class SC Waters

1. Floating solids, settleable solids, sludge deposits.

Only such amounts attributable to sewage, industrial wastes or other wastes as will not, after reasonable opportunity for dilution and mixture of same with the receiving waters, make the waters unsafe or unsuitable for fish, shellfish and wildlife, or impair the waters for any other best usage established for this class.

2. pH.

Shall be normal for the waters in the area, which generally shall range between 6.0 and 8.5, except that swamp waters may have a minimum of 4.3.

3. Dissolved oxygen.

Not less than 4.0 parts per million, except that swamp waters may have a minimum of 3.0 parts per million.

4. Toxic wastes; oils; deleterious substances; colored or other wastes; or heated liquids.

Only such amounts, whether alone or in combination with other substances or wastes, and only such temperatures as

will not render the waters injurious to fish and shellfish, adversely affect the palatability of same, or impair the waters for any other best usage established for this class.

CLASS SD

Best Usage of Waters: Navigation and any other best usage, except fishing, bathing, or shellfishing for market purposes.

Conditions Related to Best Usage: Waters will be suitable for navigation, and in certain instances where there is either no practical means of treatment known or where the degree of treatment required to satisfy the standards for a higher class is economically impractical, these waters may be used for the disposal of sewage, industrial wastes or other wastes until feasible treatment processes become available, but in no instance shall any such usage result in the development of an offensive condition.

Quality Standards for Class SD Waters

1. Floating solids; settleable solids; sludge deposits.

Only such amounts attributable to sewage, industrial wastes or other wastes as will not interfere with navigation, or cause an offensive condition.

2. pH

Not lower than 4.3 in waters used for navigation. Otherwise it shall be maintained at such levels as not to adversely affect the quality of waters in any other class to which these waters may be tributary.

3. Dissolved oxygen

Sufficient to prevent the development of an offensive condition.

4. Toxic wastes; oils; deleterious substances; colored or other wastes.

Only such amounts, whether alone or in combination with other substances or wastes and only such temperatures as will not render the waters unsuitable for navigation, or create an offensive condition.

APPENDIX D

PARTIAL SCHEDULE OF CLASSIFICATIONS ADOPTED AND ASSIGNED TO THE WATERS OF THE NORTHEAST CAPE FEAR RIVER BASIN

Name of Stream	Description	Class	Designation
Northeast Cape Fear River	From source to Wayne-Duplin County line	D	Swp. W.
Northeast Cape Fear River	From Wayne-Duplin County line to mouth of Ness Creek	C	Swp. W.
Goshen Swamp	From source to mouth of Nahunga Creek	D	Swp. W.
Goshen Swamp	From mouth of Nahunga Creek to Northeast Cape Fear River	C	Swp. W.
Maxwell Creek	From source to Northeast Cape Fear River	C	Swp. W.
Elder Branch	From source to Maxwell Creek	D	Swp. W.
Stocking Head Creek	From source to Maxwell Creek	D	Swp. W.
Island Creek	From source to Northeast Cape Fear River	D	Swp. W.
Rockfish Creek	From source to Northeast Cape Fear River	C	Swp. W.
Duffs Creek	From source to dam at Lake Tut	B	Swp. W.
Duffs Creek	From dam at Lake Tut to Rockfish Creek	D	Swp. W.
Doctors Creek	From source to Rockfish Creek	D	Swp. W.
Unnamed Tributary at Bonds Abattoir	From source to Rockfish Creek	D	Swp. W.
Little Rockfish Creek	From source to dam at Boney Mill Pond	C	Swp. W.
Little Rockfish Creek	From dam at Boney Mill Pond to Rockfish Creek	D	Swp. W.
Holly Shelter Creek	From source to Northeast Cape Fear River	C	Swp. W.
Sandy Run Swamp	From source to Holly Shelter Creek	C	Swp. W.
Shelter Swamp	From source to Holly Shelter Creek	C	Swp. W.
Angora Creek	From source to Holly Shelter Creek	C	Swp. W.
Shaken Creek	From source to Holly Shelter Creek	C	Swp. W.
Burgaw Creek	From source to first unnumbered highway bridge downstream from North Carolina Highway 53	E	Swp. W.
Burgaw Creek	From first unnumbered highway bridge downstream from N. C. Hwy. 53 to Northeast Cape Fear River	D	Swp. W.

Name of Stream	Description	Class	Designation
Island Creek	From source to Northeast Cape Fear River	D	Swp. W.
Long Creek	From source to mouth of Horse Branch Creek	D	Swp. W.
Horse Branch Creek	From source to Long Creek	D	Swp. W.
Long Creek	From mouth of Horse Branch Creek to Northeast Cape Fear River	C	Swp. W.
Northeast Cape Fear River	From mouth of Ness Creek to Cape Fear River	SC	Swp. W.
Ness Creek	From source to Northeast Cape Fear River	D	Swp. W.
Smith Creek	From source to Northeast Cape Fear River	D	Swp. W.

BIBLOGRAPHY

1. Surface Water Records of North Carolina. Surface Water Branch U. S. Geological Survey, Raleigh, North Carolina (through 1964).

2. Cape Fear River Basin Pollution Survey Report. State Stream Sanitation Committee, State Board of Health, Raleigh, North Carolina (1957).

3. Drinking Water Standards. U. S. Public Health Service, Department of Health, Education, and Welfare, U. S. Government Printing Office, Washington, D. C. (1962)

4. Babbitt, H. E. and Baumann, E. R., Sewerage and Sewage Treatment. John Wiley & Sons, Inc. (1958)

5. Nemerow, Nelson Leonard, Therories and Practices of Industrial Waste Treatment. Addison-Wesley Publishing Company, Inc. (1963).

6. Symons, James M., Weibell, Samuel R., and Robeck, Gordon G., Influence of Impoundments on Water Quality. U. S. Public Health Service Publication No. 999-WP-18 (October 1964)

7. Water Supply Characteristics of North Carolina Streams. U. S. Geological Survey Water-Supply Paper No. 1791 (1963)

8. Bayless, Jack D., Survey and Classification of the Northeast Cape Fear River and Tributaries, North Carolina. North Carolina Wildlife Resources Commission, Raleigh, N.C. (1963)

9. The Prediction of Stream Reaeration Rates. Tennessee Valley Authority, Division of Health and Safety, Environmental Hygiene Branch, Chattanooga, Tennessee (July 1962).

10. Worley, John L., "A System Analysis Method for Water Quality Management by Flow Augmentation in a Complex River Basin," Master's Thesis, Oregon State University, Published by U.S. DHEW, PHS, Portland, Oregon (June 1963).

11. New Hope Reservoir Study. U. S. Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio (May 1959).

12. Potential Water Supply Benefits Above the New Hope Dam Site. U. S. Public Health Service, Region III, Charlottesville, Virginia and Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio (March 1961).

13. Comprehensive Report on Cape Fear River Basin, North Carolina. U. S. Army Engineer District, Wilmington, North Carolina (30 October 1961).

14. Water Supply and Water Quality Control Study, Upper Cape Fear River Basin, North Carolina. FWPCA, Region III, Charlottesville, Virginia (April 1966).

15. Culp, Gordon and Culp, Russell, "Reclamation of Waste Water at Lake Tahoe." Public Works (February 1966).

16. Stephan, David G., "Water Renovation - Some Advanced treatment Processes." Civil Engineering, Vol. 35 (September 1965).

17. Kaplovsky, A. J., Walters, W. R., and Sosewitz, S., Artifical Aeration of Canals in Chicago," Journal of Water Pollution Control Federation, 36, 4, 463 (April 1964)

18. Susag, R. H., Polta, R. C., and Schroepfer, G. J., "Mechanical Surface Aeration of Receiving Waters," Journal of Water Pollution Control Federation, 38, 1, 53, (January 1966).

19. Wiley, A. J., Lueck, B. F., Scott, R. H., and Wisniewski, T. F., "Commercial-Scale Stream Federation," Journal of Water Pollution Control Federation, 34, 4, 401, (April 1966).

20. Weston, Roy F., "Studies in Entrainment Aeration," Journal of Water Pollution Control Federation, 34, 4, 342, (April 1962).

21. Waste-Water Renovation. Public Health Service Publication AWTR-4, U. S. Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, (October 1963).